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THE BUILDING MECHANICS' READY REFERENCE

CEMENT WORKERS' AND PLASTERERS' EDITION

BY

H. arry G. rant RICHEY

SUPERINTENDENT OF CONSTRUCTION U. S. PUBLIC BUILDINGS

FIRST EDITION

THIRD THOUSAND

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PREFACE.

In preparing this volume of the "Building Mechanics' Ready Reference," the author has had in mind the fact that there is very little literature available for the use of the ordinary mechanic or worker in cement and concrete. While there are a number of works devoted to cement and concrete, they are nearly all written from the engineer's point of view and for the use of engineers.

Thus in preparing this work the author has endeavored to present his ideas and information in such language, and in such a manner that it will be readily understood by the ordinary mechanic.

A large amount of information contained in the book has been reduced to tables, whereby the mechanic can at a glance find what he wishes to know and which will expedite his work.

As a large number of mechanics are engaged in both cement work and plastering, a chapter has been devoted to plasters and plastering.

A chapter on laying out work has also been incorporated, the author having deemed this necessary, owing to the rapid advancement of cement and concrete work. The mechanic now engaged upon such work, often working from drawings, should have a full knowledge of how to lay out any part of the work on which he is engaged.

The author will be pleased to hear from any reader regarding any error, typographical or otherwise, found in this work, or any idea or suggestion that may be useful in a future edition. Address the author, care of the publishers.

H. G. Richey.

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PART I.

VARIOUS CEMENTS, SPECIFICATIONS FOR CEMENTS, TESTS OF CEMENTS, ANALYSIS OF VARIOUS CEMENTS, STRENGTH OF VARIOUS CEMENTS.

Cements.—Natural cements are generally called Rosendale cement, from the name of the town in New York where it was first made in this country. It is made from a natural rock containing about 60 per cent of lime and magnesia to about 40 per cent of silica and alumina, with a little iron or potash. This cement sets and attains its limit of strength much quicker than Portland, and is used where extreme strength is not necessary. Portland cement, because the price is becoming cheaper than in former days, is now fast taking the place of Rosendale cement.

Rosendale cement is usually a dark brown; a light color indicates an inferior cement.

WEIGHT AND CHEMICAL ANALYSIS.—*Weight.*—The average weight of Louisville or Rosendale cement is as follows:

1 cubic foot, loose..................	55½ pounds.
1 cubic foot, packed................	74 "

Therefore a barrel of 265 pounds contains 4.77 cubic feet of loose cement and 3.58 cubic feet of packed cement.

Louisville cement is shipped in three kinds of packages: barrels, weighing 285 pounds gross; paper bags, 82 pounds each; and jute sacks, weighing 133 pounds each.

Chemical Analysis.—The following is a characteristic analysis of Louisville or Rosendale cement:

Silica	26.40	per cent
Alumina	6.28	"
Iron oxide	1.00	"
Lime	45.22	"
Magnesia	9.00	"
Potash and soda	4.24	"
Sulphate lime	0.00	"
Carbonic acid, water, and loss	7.86	"
	100.00	per cent

The following specifications for natural cements have been prepared and are used by the United States Engineer Department:

SPECIFICATIONS FOR NATURAL CEMENT.

(1) The cement shall be a freshly packed natural or Rosendale, dry and free from lumps. By natural cement is meant one made by calcining natural rock at a heat below incipient fusion and grinding the product to powder.

(2) The cement shall be put up in strong, sound barrels, well lined with paper so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer.

Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established brands of high-grade natural cement which have been in successful use under similar climatic conditions to those of the proposed work.)

(5) The average net weight per barrel shall not be less than 300 pounds. (West of the Allegheny Mountains this may be 265 pounds.) . . . Sacks of cement shall have the same weight as 1 barrel. If the average net weight, as determined by test weighings, is found to be below 300 pounds (265) per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply free of cost to the United States an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, time of setting, and tensile strength of the cement.

(7) Fineness.—At least 80 per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) Time of Setting.—The cement shall not acquire its initial set in less than twenty minutes and must have acquired its final set in four hours.

(9) The time of setting is to be determined from a pat of neat cement mixed for five minutes with 30 per cent of water by weight and kept under a wet cloth until finally set. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(10) Tensile Strength.—Briquettes made of neat cement shall develop the following tensile strengths per square inch, after having been kept in air for twenty-four hours under a wet cloth and the balance of the time in water:

At the end of seven days, 90 pounds; at the end of twenty-eight days, 200 pounds.

Briquettes made of one part cement and one part standard sand by weight shall develop the following tensile strengths per square inch:

After seven days, 60 pounds; after twenty-eight days, 150 pounds.

(11) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(12) The neat cement for briquettes shall be mixed with 30

per cent of water by weight, and the sand and cement with 17 per cent of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar is to be placed in the briquette mould in four equal layers, each of which is to be rammed and compressed by thirty blows of a soft brass or copper rammer three-fourths of an inch in diameter (or seven-tenths of an inch square with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. Upon completion of ramming the surplus cement shall be struck off and the layer smoothed with a trowel held nearly horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(13) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of the bids. Any cement showing, by sample, higher tests than those given must maintain the average so shown in subsequent deliveries.

(14) A cement may be rejected which fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner above specified. All expenses of such tests shall be paid by the contractor, and all such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Portland Cement.—Portland cement is what is known as a tri-calcic cement and is composed of lime, silica, alumina, iron oxide, and magnesia artificially blended together into a scientifically correct mixture and burned at a white heat. The process varies greatly with the character of the raw materials used.

By the heat of the kiln the silica, lime, alumina, and oxide of iron become silicate of lime and alumina, and aluminate of lime and ferrite of lime. If the composition of these compounds is brought about in the right proportions in the molecule and in the mass, their nature is to crystallize when wet with water, and then harden till they become as rocks.

When any lime leaves the kiln uncombined and is not changed to hydrate of lime, or carbonate of lime by exposure to the air, the uncombined lime will act as a deleterious ingredient, and is the cause of the swelling of cement in barrels and the checking and blowing found in finished cement-work; if the cement contains any of this uncombined lime it will generally show in the tests made for soundness or expansion.

Nearly all the Portland cement made in this country is produced artificially. The name "Portland" is given the cement on account of its color when hardened, which resembles the color of a stone found on the Isle of Portland, off the coast of England.

The quality of Portland cement depends on the raw materials used, their proportion, and fineness to which it is ground. Portland cement sets much slower than the natural cements and requires a much longer time to reach its limit of strength, but attains a much greater strength than the natural cement.

The color of Portland cement is a dark bluish or drab color. It should weigh at least 375 pounds per barrel and 4 sacks should equal a barrel. A cement which is lighter in weight than this is liable to be poor.

Chemical Composition.—The ordinary composition of a good Portland cement varies as follows:

Lime	from 60 to 64	per cent
Silica	from 20 to 24	"
Alumina and iron oxide	from 8 to 12	"
Magnesia	from 1 to 4	"
Alkalies	from trace to 2	"
Sulphuric acid	from 1 to 2	"

Cement containing over 4 per cent of magnesia and 2 per cent of sulphuric acid should be avoided.

The manufacturers of Portland cement will usually sell their cement under the following guarantee:

1st. The cement will stand a minimum tensile strain of 600 pounds to the square-inch section of neat briquettes kept one day in air and six days in water. 2d. The cement will stand a minimum tensile strain of 175 pounds per square-inch section, 3 parts of sand and 1 part of cement, the briquettes kept one day in air and six days in water, standard crushed quartz used in testing. 3d. The cement will stand what is known as the

boiling test. 4th. 85 per cent of this cement will pass through a No. 200 sieve. 96 per cent will pass through a No. 100 sieve. All of the barrel cement will be put up in tight packages of great strength and uniformity. The bag cement will be put up in cotton bags of superior quality, and all the weights are strictly guaranteed.

The following are the specifications used by the United States Engineering Department for Portland cement·

SPECIFICATIONS FOR AMERICAN PORTLAND CEMENT.

(1) The cement shall be an American Portland, dry and free from lumps. By a Portland cement is meant the puctrod obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime, by weight, as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions for the purpose only of regulating certain properties of technical importance to be allowable to not exceeding 2 per cent of the calcined product.

(2) The cement shall be put up in strong, sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not established itself as a high-grade Portland cement and has not for three years or more given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established

brands of high-grade Portland cement which have been made by the same mill and in successful use under similar climatic conditions to those of the proposed work for at least three years.)

(5) The average weight per barrel shall not be less than 375 pounds net. Four sacks shall contain one barrel of cement. If the weight, as determined by test weighings, is found to be below 375 pounds per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) FINENESS.—Ninety-two per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) SPECIFIC GRAVITY.—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 3.10 and 3.25.

(9) SOUNDNESS.—To test the soundness of the cement, at least two pats of neat cement, as taken from the package, mixed for five minutes with about 20 per cent of water by weight, shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the centre, tapering thence to a thin edge. The pats are to be kept under a wet cloth until finally set, when one is to be placed in fresh water for twenty-eight days. The second pat will be placed in water which will be raised to the boiling-point for six hours, then allowed to cool. Neither should show distortion or cracks. The boiling test may or may not reject at the option of the engineer officer in charge.

(10) TIME OF SETTING.—The cement shall not acquire its initial set in less than forty-five minutes and must have acquired its final set in ten hours.

(The following paragraph will be substituted for the above in case a quick-setting cement is desired:

The cement shall not acquire its initial set in less than twenty nor more than thirty minutes, and must have acquired its final set in not less than forty-five minutes nor in more than two and one-half hours.)

The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being

appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(11) Tensile Strength.—Briquettes made of neat cement, after being kept in air for twenty-four hours under a wet cloth and the balance of the time in water, shall develop tensile strength per square inch as follows:

After seven days, 450 pounds; after twenty-eight days, 540 pounds.

Briquettes made of 1 part cement and 3 parts standard sand, by weight, shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(In case quick-setting cement is desired, the following tensile strengths shall be substituted for the above:

Neat briquettes: After seven days, 400 pounds; after twenty-eight days, 480 pounds.

Briquettes of 1 part cement to 3 parts standard sand: After seven days, 120 pounds; after twenty-eight days, 180 pounds.)

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes well-dried cement and sand will be used; neat cement will be mixed with 20 per cent of water by weight, and sand and cement with 12½ per cent of water by weight. After being thoroughly mixed and worked for five minutes, the cement or mortar will be placed in the briquette mould in four equal layers, and each layer rammed and compressed by thirty blows of a soft brass or copper rammer three-quarters of an inch in diameter (or seven-tenths of an inch square, with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work

under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deem it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner herein specified. All expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

STANDARD SPECIFICATIONS FOR CEMENTS.*

PREPARED BY THE AMERICAN SOCIETY FOR TESTING MATERIALS.

1. GENERAL CONDITIONS.—All cement shall be inspected.

2. Cement may be inspected either at the place of manufacture or on the work.

3. In order to allow ample time for inspecting and testing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

4. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment.

5. Every facility shall be provided by the contractor, and a period of at least twelve days allowed for the inspection and necessary tests.

6. Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

7. A bag of cement shall contain 94 pounds of cement net. Each barrel of Portland cement shall contain 4 bags, and each

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* These specifications are now used by the U. S. Government.

barrel of natural cement shall contain 3 bags of the above net weight.

8. Cement failing to meet the seven-day requirements may be held awaiting the results of the twenty-eight-day tests before rejection.

9. All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society January 21, 1903, and amended January 20, 1904, and January 15, 1908, with all subsequent amendments thereto.

10. The acceptance or rejection shall be based on the following requirements:

Natural Cement.

11. Definition.—This term shall be applied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

12. Fineness.—It shall leave by weight a residue of not more than 10 per cent on the No. 100, and 30 per cent on the No. 200 sieve.

13. Time of Setting.—It shall not develop initial set in less than ten minutes; and shall not develop hard set in less than thirty minutes, nor in more than three hours.

14. Tensile Strength.—The minimum requirements for tensile strength for briquettes one square inch in cross-section shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

Neat Cement.

Age.	Strength.
24 hours in moist air	75 lbs.
7 days (1 day in moist air, 6 days in water)	150 "
28 " (1 " " " " 27 " " ")	250 "

One part cement, three parts standard Ottawa sand:

7 days (1 day in moist air, 6 days in water)	50 lbs.
28 " (1 " " " " 27 " " ")	125 "

15. Constancy of Volume.—Pats of neat cement about three inches in diameter, one-half inch thick at center, tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature.

(*b*) Another is kept in water maintained as near 70° F. as practicable.

16. These pats are observed at intervals for at least twenty-eight days, and, to satisfactorily pass the tests, shall remain firm and hard and show no signs of distortion, checking, cracking, or disintegrating.

Portland Cement.

17. DEFINITION.—This term is applied to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent has been made subsequent to calcination.

18. SPECIFIC GRAVITY.—The specific gravity of cement shall not be less than 3.10. Should the test of cement as received fall below this requirement, a second test may be made upon a sample ignited at a low red heat. The loss in weight of the ignited cement shall not exceed 4 per cent.

19. FINENESS.—It shall leave by weight a residue of not more than 8 per cent on the No. 100, and not more than 25 per cent on the No. 200 sieve.

20. TIME OF SETTING.—It shall not develop initial set in less than thirty minutes; and must develop hard set in not less than one hour, nor more than ten hours.

21. TENSILE STRENGTH.—The minimum requirements for tensile strength for briquettes one square inch in cross-section shall be as follows, and the cement shall show no retrogression in strength within the periods specified:

Neat Cement.

Age.	Strength.
24 hours in moist air	175 lbs.
7 days (1 day in moist air, 6 days in water)	500 "
28 " (1 " " " " 27 " " ")	600 "

One part cement, three parts standard Ottawa sand:

7 days (1 day in moist air, 6 days in water)	200 lbs.
28 " (1 " " " " 27 " " "	275 "

22. CONSTANCY OF VOLUME.—Pats of neat cement about three inches in diameter, one-half inch thick at the center, and

tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A pat is then kept in air at normal temperature and observed at intervals for at least twenty-eight days.

(*b*) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least twenty-eight days.

(*c*) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

23. These pats, to satisfactorily pass the requirements, shall remain firm and hard, and show no signs of distortion, checking, cracking, or disintegrating.

24. SULPHURIC ACID AND MAGNESIA.—The cement shall not contain more than 1.75 per cent of anhydrous sulphuric acid (SO_3), nor more than 4 per cent of magnesia (MgO).

Puzzolan Cement.—This was originally an imported cement, made from a natural burned material of volcanic origin, but the slag cements now being made are really Puzzolan cement and should be classed under that head.

The so-called slag cement is the product obtained by pulverizing, without calcination, a mixture of granulated basic blast-furnace slag and slaked lime. This product, though in reality a member of the class of Puzzolanic cements, is usually marketed as "Portland cement," in spite of the fact that it differs from a true Portland cement in method of manufacture, ultimate and rational composition and properties.

Some recent tests made with slag cement in the municipal laboratory at Vienna, gave the following results: The mortar was mixed one to three. After seven days hardening, tensile strength, 383 pounds per square inch; strength of compression, 3880 pounds per square inch. After twenty-eight days hardening, tensile strength, 551 pounds per square inch; strength of compression, 5411 pounds per square inch.

The following regarding Puzzolan or slag cement is taken from the professional papers of the United States Engineer Corps:

SLAG CEMENT.—This term is applied to cement made by intimately mixing by grinding together granulated blast-furnace slag of a certain quality and slaked lime, without calcination subsequent to the mixing. This is the only cement of the Puzzolan class to be found in our markets (often branded as Portland), and as true Portland cement is now made having

slag for its hydraulic base, the term "slag cement" should be dropped and the generic term *Puzzolan* be used in advertisements and specifications for such mixtures not subsequently calcined.

Puzzolan cement made from slag is characterized physically by its light lilac color; the absence of grit attending fine grinding and the extreme subdivision of its slaked-lime element; its low specific gravity (2.6 to 2.8) compared with Portland (3 to 3.5); and by the intense bluish-green color in the fresh fracture after long submersion in water, due to the presence of sulphides, which color fades after exposure to dry air.

The oxidation of sulphides in dry air is destructive of Puzzolan cement mortars and concretes so exposed. Puzzolan is usually very finely ground, and when not treated with soda sets more slowly than Portland. It stands storage well, but cements treated with soda to quicken setting become again very slow-setting from the carbonization of the soda (as well as the lime) element after long storage.

Puzzolan cement properly made contains no free or anhydrous lime, does not warp or swell, but is liable to fail from cracking and shrinking (at the surface only) in dry air.

Mortars and concretes made from Puzzolan approximate in tensile strength similar mixtures of Portland cement, but their resistance to crushing is less, the ratio of crushing to tensile strength being about 6 or 7 to 1 for Puzzolan and 9 to 11 to 1 for Portland. On account of its extreme fine grinding Puzzolan often gives nearly as great tensile strength in 3 to 1 mixtures as neat.

Puzzolan permanently assimilates but little water compared with Portland, its lime being already hydrated. It should be used in comparatively dry mixtures well rammed, but while requiring little water for chemical reactions, it requires for permanency in the air constant or continuous moisture.

Proper Uses of Puzzolan Cement.—Puzzolan cement never becomes extremely hard like Portland, but Puzzolan mortars and concretes are tougher or less brittle than Portland.

The cement is well adapted for use in sea-water, and generally in all positions where constantly exposed to moisture, such as in foundations of buildings, sewers, and drains, and in underground works generally, and in the interior of heavy masses of masonry or concrete.

It is unfit for use when subjected to mechanical wear, attrition, or blows. It should never be used where it may be exposed for

long periods to dry air, even after it has well set. It will turn white and disintegrate, due to the oxidation of its sulphides at the surface under such exposure.

Sulphuretted hydrogen, which is often evolved upon decomposition of the sulphides in Puzzolan cement, is injurious to iron and steel.

Such metals, if used in connection with Puzzolan cement should be protected, or an allowance be made for deterioration by increase of section."

Some more recent tests of slag cements show that they contain very little sulphur and analyses show their composition to be practically the same as the best brands of Portland cements.

SPECIFICATIONS FOR PUZZOLAN CEMENT.

PREPARED BY THE U. S. ENGINEER DEPARTMENT.

(1) The cement shall be a Puzzolan of uniform quality, finely and freshly ground, dry, and free from lumps, made by grinding together without subsequent calcination granulated blast-furnace slag with slaked lime.

(2) The cement shall be put up in strong sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed, and for any brand from cement works that do not make and test the slag used in the cement,

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor.

No cement will be allowed to be used except established brands of high-grade Puzzolan cement which have been in

successful use under similar climatic conditions to those of the proposed work and which come from cement works that make the slag used in the cement.

(5) The average weight per barrel shall not be less than 330 pounds net. Four sacks shall contain 1 barrel of cement. If the weight as determined by test weighings is found to be below 330 pounds per barrel, the cement may be rejected or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) Fineness.—Ninety-seven per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) Specific Gravity.—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 2.7 and 2.8.

(9) Soundness.—To test the soundness of cement, pats of neat cement mixed for five minutes with 18 per cent of water by weight shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the centre, tapering thence to a thin edge. The pats are to be kept under wet cloths until finally set, when they are to be placed in fresh water. They should not show distortion or cracks at the end of twenty-eight days.

(10) Time of Setting.—The cement shall not acquire its initial set in less than forty-five minutes and shall acquire its final set in ten hours. The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to one-fourth pound weight The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to 1 pound weight.

(11) Tensile Strength.—Briquettes made of neat cement, after being kept in air under a wet cloth for twenty-four hours and the balance of the time in water, shall develop tensile strengths per square inch as follows:

After seven days, 350 pounds; after twenty-eight days, 500 pounds.

Briquettes made of one part cement and three parts standard sand by weight shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes neat cement will be mixed with 18 per cent of water by weight, and sand and cement with 10 per cent of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar will be placed in the briquette mould in four equal layers and each layer rammed and compressed by thirty blows of a soft brass or copper rammer, three-quarters of an inch in diameter or seven-tenths of an inch square, with rounded corners, weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized testing laboratory in the manner herein specified, all expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Silica Cement, or Sand Cement.—This is a patented article manufactured by grinding together silica or clean sand

with Portland cement, by which process the original cementing material is made extremely fine and its capacity to cover surfaces of concrete aggregates is much increased.

The sand is an adulteration, but on account of the extreme fineness of the product it serves to make mortar or concrete containing a given proportion of pure cement much more dense, the finer material being increased in volume.

The increase in cementing capacity due to the fine grinding of the cement constituent offsets, in great degree, the effects of the sand adulteration, so that sand cement made from equal weights of cement and sand approximates in tensile strength to the neat cement, and the material is sold as cement.

The extreme fine grinding also improves cement that contains expansives, but nevertheless sand cement should not be purchased in the market, but should be made on the work from approved materials if used for other purposes than for grouting, for which it is peculiarly adapted.

SHORT SPECIFICATIONS FOR CEMENTS.

Natural Cement.—All natural cement must have a specific gravity of not less than 2.70, must be of such fineness that 80 per cent will pass through a No. 100 standard sieve, and briquettes made of such neat natural cement, after exposure to the air for one day and immersion in water for six days, must show a tensile strength of 90 pounds to the square inch. Pats ½ inch thick must stand same test hereinafter specified for Portland cement.

Portland Cement.—All Portland cement must have a specific gravity of not less than 3.10, must be of such fineness that 90 per cent will pass through a No. 100 standard sieve, must not contain more than 2 per cent anhydrous sulphuric acid, nor 4 per cent magnesia, and briquettes made of such neat Portland cement, after exposure to the air for one day and immersion in water for six days, must show a tensile strength of 350 pounds to the square inch. One-half-inch pats exposed to the air for seven days or immersed in water for the same time after hard set shall show no blotches, discolorations, checks, or signs of disintegration.

Non-staining Cement.—Non-staining cement must be of a brand that has been in use for at least two years to test its

non-staining qualities, have a specific gravity of not less than 2.75, contain not more than 2 per cent sulphuric acid, nor more than 4 per cent magnesia, be of such fineness that 85 per cent will pass through a No. 100 standard sieve, and briquettes of the neat cement, tested as specified for Portland cement, shall have a tensile strength of 200 pounds per square inch.

All cement must be of uniform quality and when delivered must be in original packages with the brand and maker's name marked thereon, and must be kept dry.

Tests, etc., of Cement.—In ordinary work the purchaser can be guided as to the quality of the cement by the brand and name of the manufacturer, unless the cement is of a standard brand and make, and which has been thoroughly tested in the past by use, etc., it should not be used on any important work until it has been tested. This is best done at some laboratory equipped for the purpose.

The following rules have been adopted by the U. S. Engineer Corps for testing cement, and should be a good guide for any person testing cement.

General Considerations.—The constructing engineer is confronted by no problem more difficult than to decide whether a certain cement, when placed in a work, will behave in a predetermined way. This is especially true of Portlands. Other cements are much more reliable under conditions of exposure for which they are suited.

The difficulties arise from the fact that tests for acceptance or rejection must be made on a product not in its final stage. A cement, when incorporated in masonry, undergoes for months chemical changes in the process of setting, so that the material subjected to strains in the work is not the material tested, but a derivative of it. The object of tests is to establish two probabilities: First, that the product of the given cement will develop the desired strength and hardness soon enough to enable it to bear the stresses designed for it; second, that it will never thereafter fall below that strength and hardness. Up to the present time it appears that the relation between the chemical and physical properties of raw cement and of its partially indurated derivatives, determined by tests, and the physical properties of the same cement or its derivatives, after complete hydration and induration in the work, can be stated only within rather wide limits.

The most useful tests of cements are those, first, which connect themselves definitely with some serious defect to which cements are subject, or with some merit which they should possess; second, which can be made with the least apparatus and manipulation, and which give their indications in the shortest time; and, third, which are freest from personal equation and from influences of local surroundings. These criteria, applied to the customary tests of cements, give indications as to their relative value and the best methods of making them.

TEST OF GRINDING.—This test derives importance from the fact, apparently well established, that, other things being equal, the finer the cement the greater will be its sand-carrying capacity; that is, it will show greater strength with the same charge of sand, or equal strength with a greater charge. According to the best information the Board can obtain, the cementitious value of this material is believed to reside principally, if not wholly, in the very fine part. It follows that a grinding test should be directed to determining the proportion which it very fine rather than the residue above a certain size. The Board does not propose any change in the accepted grinding test of Portland cement, but favors for natural cement the use of the same size screen as for Portland, No. 100, with the requirement that 80 per cent shall pass through it. The screen should be frequently examined, magnified, if practicable, to see that no wires are displaced, leaving apertures larger than the normal.

TEST FOR SPECIFIC GRAVITY.—This test is made with simple appliances, and its result is immediately known. It appears to connect itself quite definitely with the degree of calcination which the cement has received. The higher the burning, short of vitrification, the better the cement and the higher the specific gravity.

This test has another value, in that the adulterations of Portland cement most likely to be practised and most to be feared are made with materials which reduce the specific gravity. The test is therefore of value in determining a properly burned, non-adulterated Portland. If underburned, the specific gravity may fall below 3; it may reach 3.5 if the cement has been overburned. No other hydraulic cement is so heavy in proportion to volume, natural cement having a specific gravity of about 2.5 to 2.8 and Puzzolan (slag) of about 2.7 to 2.8. Properly burned Portland, adulterated with slag, will fall below 3.1.

TEST OF ACTIVITY.—This test, made by gauging the cement with water and observing the times of initial and permanent set, is partly direct and partly indirect. It is direct in so far as its limits relate to the time necessary to get the cement in place after mixing, which must not be greater than the time of initial set, and to the time within which the cement product must take its load, which must not be less than the time of permanent set. It is indirect in so far as its limits relate to the probable final strength, elasticity, and hardness of the cement mixtures. In the latter respect it appears to be reasonably well established that cements exhibiting great activity give, after long periods, results inferior to those with action less rapid.

The test for activity is easily made with simple appliances, and its results are known in a few hours at most. Variable results in the test are caused by different local conditions of moisture and temperature and by the different judgments of observers as to whether the needles penetrate or not. Generally speaking, both periods of set are lengthened by increase of moisture and shortened by increase of temperature. Some manufacturers claim that their cements show their best results when gauged with particular percentages of water. It is not considered good policy to encourage these peculiarities at the expense of the uniformity of tests which is so greatly desired. It is better to adopt a definite proportion of water for gauging and require all cements of the same class to stand or fall on their showing when so gauged. Such a percentage, adopted and known, will probably be used by manufacturers in testing goods sold to the Engineer Department, and a greater harmony between mill and field tests of the same cement will result.

In gauging Portland cement the samples should be thoroughly dried before adding water. This precaution is not deemed necessary with natural cement. Sufficient uniformity of temperature will result if the testing-room be comfortably warmed in winter and the specimens be kept out of the sun in a cool room in summer and under a damp cloth until set.

TEST FOR CONSTANCY OF VOLUME.—This test results from observations made on the pats or cakes used in the setting test. It derives its value from its connection with the quantity of expansives in the cement.

The test is easy to make, and its results are relatively free

from personal error, though there is room for a difference of judgment as to the appearance of the cakes. As they may be preserved and the decision reviewed at any time on the original data, such differences are immaterial.

TESTS OF STRENGTH.—These may be subdivided into compressive and tensile tests, the latter including the transverse test made by breaking a beam of the cement. The compressive test need not be further considered, as it is less easily made than the tensile test and gives no surer indications. The ratio of compressive to tensile strength of the same class of cements is quite uniform.

Of the tensile tests the direct pull is preferable to the flexure test.

The tensile test is theoretically a perfect index of the quality of the cement at the periods of test, and a comparison at different periods gives the best obtainable indication of what its subsequent conduct will be. In the opinion of the Board the two periods most generally adopted, seven and twenty-eight days after mixing, are, on the whole, the best. The one-day test, though of some value in a discriminating sense, should not be placed in the same category as the other periods named.

The apparatus for tensile tests is somewhat elaborate and delicate, but is of standard manufacture and readily obtainable at relatively small cost.

In respect of uncertainties due to the personal equation of the tester and to the influence of local conditions this test presents greater difficulties than any of the others considered. The most scrupulous care must be observed in the manipulations, and the tester should possess natural aptitude for such work. The object is to determine the greatest stress per square inch which the cement can be made to stand under given conditions without rupture. If the conditions have been carefully observed and several discrepant results are obtained, the highest may be right, but the others are certainly wrong. No averaging should be done.

The remarks made above under the activity test as to the relation between early hydraulic intensity and the final excellence of a cement product are equally applicable to the indications from tensile tests. A cement which tests moderately high at seven days and shows a substantial increase to twenty-eight days is more likely to reach the maximum strength slowly

and retain it indefinitely with a low modulus of elasticity than a cement which tests abnormally high at seven days with little or no increase at twenty-eight days.

ACCELERATED TESTS.—The rules recommended by the committee of the American Society of Civil Engineers in 1885 have been substantially accepted here and abroad as to tests of setting qualities and soundness; more rapid tests for soundness are, however, proposed and practised, though no accelerated test has been generally accepted.

Accelerated tests proposed for the speedy detection of the presence of expansives in cement usually consist in the application, after gauging, of dry heat or of immersion in warm or boiling water or steam. The immersion tests are most in vogue. They vary from immersing freshly gauged pats on glass plates in water at 115° F. for twenty-four hours, or at higher temperatures for various periods, to steaming or boiling cakes or cylinders of the material to be tested at 212° F. for varying times.

In France and Germany the swelling or expansion of boiled cylinders is measured directly by calibration. Usually change of volume not accompanied by visible evidences of it—i.e., distortion or disruption—is not observed in American tests prescribed in specifications for the reception of cements. Of all these tests the boiling test is the simplest, requires only apparatus everywhere available, and is recommended by the Board. It has been the experience that this test detects material that is unsound by reason of the presence of active expansives; but in some cases it rejects material that would give satisfactory results in actual work and will reject material that would stand this test after air slaking.

The great value of the test lies in its short-time indications and in at once directing attention to weak points in the cement to be further observed or guarded against. Of two or more cements offered for use or on hand, the cements that stand the boiling tests are to be taken preferably; it should be constantly applied on the work among other simple tests to be noted, for although the boiling test sometimes rejects suitable material, it is believed that it will always reject a material unsound by reason of the existence of active expansives. Sulphate of lime, while enabling cements to pass the boiling tests, introduces an element of danger.

This test is proposed as suggestive or discriminative only.

Except for works of unusual importance it is nót recommended that a cement passing the other tests proposed shall be rejected on the boiling test.

Tests to be Made.—For selecting Portland and Puzzolan cements from among the brands offered, the Board recommends that the following tests be made:

1. For fineness of grinding.
2. For specific gravity.
3. For soundness or constancy of volume in setting.
4. For time of setting.
5. For tensile strength.

For natural cement we recommend the omission of the specific-gravity and soundness tests.

On the works the Board recommends simple tests when the more elaborate tests cannot well be made.

In determining the minimum requirements for cements given in the subjoined specifications we recognize that many cements that attain only fair strength neat and with sand in a short time and show marked gains of strength on further time will fulfil the requirements of the service, and that unusually high tensile strength attained in a few days after gauging is often coupled with a small or negative increase in strength in further short intervals. Unusually high tests in a short time after gauging should be regarded with suspicion, although some well-known brands of American cements show great strength in short-time tests and, so far as observed, are reliable in air and fresh water. Cements offered under such known brands should show their characteristic strength and other qualities or be suspected as spurious or adulterated, if not rejected, even though the minimum requirements of the specifications are met. The practice of offering a bonus or free gift of money in addition to the contract price for cement testing above a fixed high point should be prohibited as unnecessary, for cements so obtained are likely to be unsound in a manner not easily detected in the time usually available in testing.

It is believed that most of the very high-testing Portland cements have lime in excess, the effect of which is temporarily masked by the use of sulphate of lime. Overlimed cements so treated are unfit for use in sea-water. For such uses a chemical analysis should be required, and the quantity of sulphuric acid, as well as magnesia, be limited to a low per-

centage.[1] It is not yet known that sulphate of lime in quantity less than 2 per cent is injurious to cements to be used in fresh water or in air. It masks expansives that might ultimately cause the destruction of the work, but it is not known whether this effect is permanent. Its addition is now deemed necessary to control time of setting. It makes a quick-setting cement slow setting, at the same time increasing tensile strength acquired in a short time.

MANIPULATION OF CEMENTS FOR TESTS.—*I. Fineness.*—Place 100 parts (denominations determined by subdivisions of the weighing-machine used) by weight on a sieve with 100 holes to the linear inch, woven from brass wire No. 40, Stubb's wire gauge; sift by hand or mechanical shaker until cement ceases to pass through.

The weight of the material passing the sieve plus the weight of the dust lost in air, expressed in hundredths of the original weight, will express the percentage of fineness. In order to determine this percentage the residue on the sieve should be weighed.

It is only the impalpable dust that possesses cementitious value. Fineness of grinding is therefore an essential quality in cements to be mixed with sand. The residue on a sieve of 100 meshes to the inch is of no cementitious value, and even the grit retained on a sieve of 40,000 openings to the square inch is of small value. The degree of fineness prescribed in these specifications (92 per cent) for Portland through a sieve of 10,000 meshes to the square inch is quite commonly attained in high-grade American cements, but rarely in imported brands. On the Pacific Coast, where foreign cements mainly are in the market, this requirement may be lowered for the present to 87 per cent on No. 100 sieve.

II. Specific Gravity.—The standard temperature for specific-gravity determinations is 62° F., but for cement testing temperatures may vary between 60° and 80° F. without affecting results more than the probable error in the observation.

Use any approved form of volumenometer or specific-gravity bottle, graduated to cubic centimeters with decimal subdivisions. Fill instrument to zero of the scale with benzine, turpentine, or some other liquid having no action upon cements.

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[1] Not more than 4 per cent, by weight, of magnesia, 2 per cent of sulphuric anhydride, or 2 per cent of sulphate of lime should be allowed in any case. In sea-water not exceeding one-half these quantities.

Take 100 grams of sifted cement that has been previously dried by exposure on a metal plate for twenty minutes to a dry heat of 212° F., and allow it to pass slowly into the fluid of the volumenometer, taking care that the powder does not stick to the sides of the graduated tube above the fluid and that the funnel through which it is introduced does not touch the fluid.

Read carefully the volume of the displaced fluid to the nearest fraction of a cubic centimeter. Then the approximate specific gravity will be represented by 100 divided by the displacement in cubic centimeters.

The operation requires care.

III. Setting Qualities and Soundness.—The quantity of water and the temperature of water and air affect the time of setting. The specifications contemplate a temperature varying not more than 10° from 62° F. and quantities of water given herein:

For Portland cements use about 20 per cent of water.

For Puzzolan cements use about 18 per cent of water.

For natural cements use about 30 per cent of water.

These quantities are for the cements as taken from the packages.

Mix thoroughly for five minutes, vigorously rubbing the mixture under pressure; time to be estimated from moment of adding water and to be considered of importance.

Make on glass plates two cakes from the mixture about 3 inches in diameter, $\frac{1}{2}$ inch thick at middle, and drawn to thin edges, and cover them with a damp cloth or place them in a tight box not exposed to currents of dry air. At the end of the time specified for initial set apply the needle $\frac{1}{12}$ inch diameter weighted to $\frac{1}{4}$ pound to one of the cakes. If an indentation is made the cement passes the requirement for initial setting, if no indentation is made by the needle it is too quick-setting. At the end of the time specified for "final set" apply the needle $\frac{1}{24}$ inch diameter loaded to 1 pound. The cement cake should not be indented.

Expose the two cakes to air under damp cloth for twenty-four hours. Place one of the cakes, still attached to its plate, in water for twenty-eight days; the other cake immerse in water at about 70° temperature supported in a rack above the bottom of the receptacle; raise the water gradually to the boiling-point and maintain this temperature for six hours and then let the water with cake immersed cool. Examine the

cakes at the proper time for evidences of expansion and distortion. Should the boiled cake become detached from the plate by twisting and warping or show expansion cracks the cement may be rejected, or it may await the result of twenty-eight days in water. If the fresh-water cake shows no evidences of swelling, the cement may be used in ordinary work in air or fresh water for lean mixtures. If distortion or expansion cracks are shown on the fresh-water cake, the cement should be rejected.

Of two or more cements offered, all of which will stand the fresh-water-cake test for soundness, the cements that will stand the boiling tests also are to be preferred.

IV. Tensile Strength.—Neat Tests: Use thoroughly dried unsifted cements.[1] Place the amount to be mixed on a smooth, non-absorbent slab; make a crater in the middle sufficient to hold the water; add nearly all the water at once, the remainder as needed; mix thoroughly by turning with the trowel, and vigorously rub or work the cement for five minutes.

Place the mould on a glass or slate slab. Fill the mould with consecutive layers of cement, each when rammed to be ¼ inch thick. Tap each layer 30 taps with a soft brass or copper rammer weighing 1 pound and having a face ¾ inch diameter or 7/10 inch square with rounded corners. The tapping or ramming is to be done as follows: While holding the forearm and wrist at a constant level, raise the rammer with the thumb and forefinger about ½ inch and then let it fall freely, repeating the operation until the layer is uniformly compacted by 30 taps.

This method is intended to compact the material in a manner similar to actual practice in construction, when a metal rammer is used weighing 30 pounds, with circular head 5 inches in diameter falling about 8 inches upon layers of mortar or concrete 3 inches thick. The method permits comparable results to be obtained by different observers.

After filling the mould and ramming the last layer, strike smooth with the trowel, tap the mould lightly in a direction parallel to the base plate to prevent adhesion to the plate, and

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[1] The hot clinker is often suddenly chilled by steam or water in order to reduce the work of grinding by first cracking it. This water, as well as that absorbed from the air, should always be expelled or its percentage ascertained and deducted from the amounts prescribed for briquettes. Sand, also, should be similarly treated.

cover for twenty-four hours with a damp cloth. Then remove the briquette from the mould and immerse it in fresh water, which should be renewed twice a week for the specified time if running water is not available for a slow current. If moulds are not available for twenty-four hours, remove from the moulds after final set, replacing the damp cloth over the briquettes. In removing briquettes before hard set great care should be exercised. Hold the mould in the left hand and, after loosening the latch, tap gently the sides of the mould until they fall apart. Place the briquettes face down in the water trough.

For neat tests of Portland cement use 20 per cent of water by weight.

For neat tests of Puzzolan cement use 18 per cent of water by weight.

For neat tests of natural cement use 30 per cent of water by weight.

Nearly all this water is retained by Portland cement, whereas only about one-third of the gauging water is retained by Puzzolan or natural cements; from this it follows that an apparent condition of plasticity or fluidity that ultimately little injures Portland paste, very seriously injures Puzzolan or natural mortars and concretes by leaving a porous texture on the evaporation of the surplus water.

Sand Tests.—The proportions 1 cement to 3 sand are to be used in tests of Puzzolan and Portland, and 1 cement to 1 sand in tests of natural or Rosendale cements. Crushed quartz sand, sifted to pass a standard sieve with 20 meshes per linear inch and to be retained on a standard sieve with 30 meshes to the inch, is to be used.

After weighing carefully, mix dry the cement and sand until the mixture is uniform, add the water as in neat mixtures, and mix for five minutes by triturating or rubbing together the constituents of the mortar. This may be done under pressure with a trowel or by rubbing between the fingers, using rubber gloves. The rubbing together seems necessary to coat thoroughly the facets of the sand with the cement paste.

It is found that prolonged rubbing, when not carried beyond the time of the initial set, results in higher tests. Five minutes is the time of mixing quite generally adopted in European specifications. The briquettes are to be made as prescribed for neat mixtures.

Portland cements well dried require water from 10 to 12½ per cent by weight of constituent sand and cement for maximum ultimate strength in tested briquettes.

Puzzolan, about 9 to 10 per cent.

Natural, about 15 to 17 per cent.

Mixtures that at first appear too dry for testing purposes often become more plastic under the prolonged working required herein.

In general, about four briquettes constitute the maximum number that may be made well within the time required for initial setting of moderately slow-setting cements.

Three such batches of sand mixtures should be made, and one briquette of each batch may be broken at seven and twenty-eight days, giving three tests at each period. At least one batch of neat cement briquettes should be made.

If the first briquette broken at each date fulfils the minimum requirement of these specifications it is not necessary to break others which may be reserved for long-time tests.

If the first briquette does not pass the test for tensile strength, then briquettes may be broken until six briquettes, two from each batch, have been broken at seven days, and the remaining six reserved for twenty-eight-day tests. The highest result from any sample is to be taken as the strength of the sample when the break is at the least section of briquette.

If, on the twenty-eight-day tests, the cement not only more than fulfils the minimum requirements of these specifications, but also shows unusual gain in strength, it may still be accepted if the other tests are satisfactory, notwithstanding a low seven-day test, if early strength is not a matter of importance. Such cements are likely to be permanent.

For a batch of four briquettes, the following quantities are suggested as in accord with these specifications. Water is measured by fluid-ounce volumes, not by weight, temperature varying not more than 10° from 62° F.

Portland Cement.—Neat: 20 ounces of cement, 4 ounces of water. Mix wet five minutes.

Sand: 15 ounces sand, 5 ounces cement, 2½ ounces water. Mix thoroughly dry; then mix wet five minutes.

Puzzolan Cement.—Neat: 20 ounces cement, 3¾ ounces water. Mix wet five minutes.

Sand: 15 ounces sand, 5 ounces cement, 2 ounces water. Mix thoroughly dry; then mix wet five minutes.

Natural Cement.—Neat: 20 ounces cement, 6 ounces water. Mix wet five minutes.

Sand: 10 ounces cement, 10 ounces sand, $3\frac{1}{2}$ ounces water. Mix dry; then wet for five minutes.

For measuring tensile strength, a machine that applies the stress automatically at a uniform rate is preferable to one controlled entirely by hand.

These specifications for tensile strength contemplate the application of stress at the rate of 400 pounds per minute to briquettes made as prescribed herein. A rate so rapid as to approximate a blow or so slow as to approximate a continued stress will give very different results.

The tests for tensile strength are to be made immediatcly after taking from the water or while the briquettes are still wet. The temperature of the water during immersion should be maintained as nearly constant as practicable; not less than 50° nor more than 70° F.

The tests are to be made upon briquettes 1 inch square at place of rupture. The specifications contemplate the use of the form of briquette recommended by the committee of the American Society of Civil Engineers, held when tested by close-fitting metal clips, without rubber or other yielding contacts. The breaks considered in the tests are to be those occurring at the smallest section, 1 inch square.

Simple Tests.—Tests of cement received upon a work in progress must often be of much simpler character than prescribed herein.

Tests on the work are mainly to ascertain whether the article supplied is genuine cement, of a brand previously tested and accepted, and whether it is a reasonably sound and active cement that will set hard in the desired time, and give a good, hard mortar. Simple tests may give this information, and such should be multiplied whether or not more elaborate tests be made. Pats and balls of cement and mortar from the storehouse and mixing platform or machine should be frequently made. The setting or hardening qualities, as determined roughly by estimating time and by pressure of the thumb-nail, should be observed; the hardness of the set and strength, by cracking the hardened pats or cakes between the fingers, and by dropping the balls from the height of the arm upon a pavement or stone and observing the result of the impact.

By placing the pats in water as soon as hardened sufficiently

and raising the temperature to the boiling-point for a few hours and observing the character and color of the fracture after sufficient immersion, information as to the character of the material, whether hydraulic, a Portland, or Puzzolan, whether too fresh or possibly "blowy," may be speedily and quite well ascertained without measuring instruments.

Many engineers and users of cements regard such simple tests, taken in connection with the weight and fineness of the cement and the apparent texture and hardness of the mortars and concretes in the work, sufficient field tests of a material of known repute. The more elaborate tests, described above, should be made in well-equipped laboratories by skilled cement testers.

Classification of Tests.—The tests to be made are two classes.

(1) Purchase tests on samples furnished by bidders to ascertain whether the bidder may be held on the sample to the delivery of suitable material, should his offer be accepted.

(2) Acceptance tests on samples taken at random from deliveries, to ascertain whether the material supplied accords with the purchase sample, or is suitable for the purpose of the work, as stated in the specifications for cement supplies.

(1) *Purchase tests.*—Under these specifications bids for Portland cements will be restricted to brands that have been approved after at least three years' exposure in successful use under similar conditions to those of the proposed work. This specification limits proposals to manufacturers of cement of established repute, and in so far lessens the dependence to be placed upon tests of single samples of cement in determining the probable quality of the cements offered, that sample packages may not be required with the proposals when the brand is known to the purchaser. When the cement is not known to the purchasing officer by previous use, a barrel of it should be required as representing the quality of cement to be supplied. A full set of tests should be made from this sample, and subsequent deliveries be required to show quality at least equal to the sample.

In this connection it is advisable in districts where well-equipped laboratories have been established, that sample packages of the cements in use in that territory, as sold in the open market, be obtained and tested as occasion offers to ascertain the characteristic qualities of the brands as commer-

cial articles, the information to be used in subsequent purchases of cements.

When purchase samples are waived, acceptance tests should be based upon the known qualities of the brand, as shown by previous tests.

The sample barrel should not be broken further than to take therefrom the necessary samples for testing. Afterwards it should be put away in a dry place and kept for further testing, should the results obtained be disputed.

(2) *Acceptance tests.*—The tests to be made on cements delivered under contract depend not only on the extent, character, and importance of the work itself, but also on the time available between the delivery and the actual use of the material.

(*a*) On very important and extensive works, equipped with a testing laboratory and adequate storehouses, where cement may be kept at least thirty days before being required for use, full and elaborate tests should be made, keeping in view the fact that careful tests of few samples are more valuable than hurried tests of many samples.

(*b*) On active works of ordinary character, when time will not permit full tests, and on small works where the expenses of laboratory are not justified, the tests must necessarily be limited to such reasonable precautions against the acceptance and use of unfit material as may be taken in the usually short interval between the receipt and use of the material.

Such conditions were in view in formulating the specification that proposals will be received from manufacturers of such cements only as have been proved by at least three years' use under similar conditions of exposure. Of the tests named in the specifications, those for fineness, activity or hydraulicity, specific gravity, weight of packages, and accelerated tests for indications as to soundness, may be made within two days after the receipt of the material and with a very small outlay for instruments.

Cement of established repute, shown by specific gravity and fineness to be properly burnt and ground, or normal for the brand, that will set hard in reasonable time, the cakes snapping with a clean fracture when broken between the fingers, and standing the tests above named, may be accepted and used with reasonable certainty of success. Nevertheless, packages taken at random from the deliveries should occasionally be set aside and samples taken therefrom sent to a testing

laboratory for the more elaborate tests for tensile strength (and for soundness should the boiling tests not be conclusive). The final acceptance and payment for such cement as may not have been actually placed in the work should, by agreement, be made to depend upon such tests.

In all cases where cement has been long stored it should be carefully tested before use to ascertain whether it has deteriorated in strength.

Should the simple tests give unsatisfactory or suspicious results, then a full series of tests should be carefully made.

When Portland cement is in question the specific-gravity and fineness tests should be made to guard against adulteration, and in all cases test weighings should be made to guard against short weights.

In cases where the amount of cement or the importance of the work will not justify the purchase of the simple apparatus required for the specific gravity, fineness, and boiling tests, the cement can be accepted on the informal tests mentioned herein, which require no apparatus whatever, but in such cases cements well known to the purchaser by previous use should be selected and purchased directly from the manufacturer or his selling agent in order that responsibility for the cement may be fixed.

Certified tests by professional inspectors made as prescribed herein on samples taken from the cement to be shipped to the work, in a manner analogous to that cutsomary among engineers in the purchase of structural steel and iron, may be required in such cases.

SAMPLING.—The entire package from parts of which tests are to be made is to be regarded as the sample tested. It should be marked with a distinctive mark that must also be applied to any part tested. The package should be set aside and protected against deterioration until all results from tests made from it are reached and accepted by both parties to the contract for supplies.

Cement drawn from several sample packages should not be mixed or mingled, but the individuality of each sample package should be preserved.

In testing it should be borne in mind that a few tests from any sample, carefully made, are more valuable than many made with less care.

The amount of material to be taken for formal tests is indicated herein where weights of the constituents of four briquettes are given, to which should be added the amount necessary for the tests for specific gravity, activity, and soundness.

In extended tests the material should be taken from the sample package from the heads and centre of barrel, and from the ends and centre of bag, by such an instrument as is used by inspectors of flour. All material taken from the same sample package may be thoroughly mixed or mingled and the tests be made therefrom as showing the true character of the contents of the sample package.

In making formal tests at the work for acceptance of cement sample packages should be taken at random from among sound packages. The number taken must depend upon the importance and character of the work, the available time, and the capacity of the permanent laboratory force. For tensile strength the tests with sand are considered the more important and should always be made. Tests neat should be made if time permits.

It is not necessary in any case on a large work to test more than 10 per cent of the deliveries, even of doubtful cement, and a much less number of samples may be taken should no cause for distrust be revealed by the tests made. In very important work of small extent each package may be tested. A cement should be rejected if the samples show dangerous variation in quality or lack of care in manufacture and resulting lack of uniformity in the produce without regard to the proportion of failures among samples tested.

In all cases in the use of cements the informal or simple tests of the character named herein should be constantly carried on. These constitute most valuable tests. Whenever any faulty material is indicated by such tests, elaborate tests should be at once instituted and should the fault be confirmed, the cement delivered and not used should be rejected and the use of the brand be discontinued.

Tests for Weight.—From time to time packages should be weighed in gross and afterwards the weight of neat cement and tare of the packages determined. If short weight of neat cement is indicated, a sufficient number of packages should be weighed and the average net weight per package ascertained with sufficient certainty to afford a satisfactory basis of settlement.

The user of cement may make some simple tests to determine the quality of the cement as follows:

SOUNDNESS.—To test the soundness of the cement, take a lamp-chimney with a large swell to it and stand it on end; fill it with dry cement and then pour water on the cement; if the glass cracks the cement is unfit for use in any damp place.

The cement can be tested as to the time the initial set takes place; as a rule the longer it takes the cement to set the stronger it will be.

A simple test can be made by mixing some cement with just enough water to make it plastic, and roll it into a ball about the size of a walnut; after it sets in the air for about two hours, place it under water for three or four days If it gradually becomes harder with no cracks it is an indication of good cement.

EXPANSION.—A cement that will expand should not be used. To test this make a cake of cement and let it remain in the air until it sets, then put it under water for a few days; if any cracks appear around the edge of the cake it indicates expansion and should be rejected. This sometimes happens with newly made cement, and age will overcome it. The test for soundess will also generally show if the cement will expand.

NON-STAINING CEMENT.—In setting or pointing marble or limestones or other porous stones a reliable brand of a non-staining cement should be used, as Portland or Rosendale cement will stain the stone enough to disfigure it. This is a patent cement called La Farge, which is usually made from a limestone having hydraulic qualities. Some of the foreign Puzzolan cements also possess this non-staining feature.

PRACTICAL CEMENT TESTS NOT REQUIRING A LABORATORY.*

The purchaser can send samples of cement to chemists or engineers who make a specialty of such work, or he can purchase some of the apparatus they use and make the tests himself. An outfit will cost not less than $200, and may run up as high as a man wishes to go. To make tests with the regulation apparatus

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* By Ernest McCullough, C. E., Chicago, Ill.

requires a well-trained man, and it is not possible that all cement users will become expert. Neither is it likely that all cement users will go to the expense of having cement tested by experts.

There are many cements on the market, and all dealers do not know the difference between them. Long storage under improper conditions has a bad effect on Portland cement. It is therefore a proper thing that cement users should know what tests to make to enable them to secure a Portland cement, and also to know when that is of good quality.

The writer proposes to describe a few simple tests any intelligent man can make, and the total cost of the apparatus should be less than ten dollars.

FINENESS.—It is agreed that the impalpable dust alone possesses cementitious properties. Fineness of grinding is therefore an essential quality in cements to be mixed with sand.

Weigh in a balance (not spring scales) two or three ounces of cement. It is well to use the metric system of weights, so that percentages can be readily determined. Place about fifty grams in a standard No. 100 sieve with cover. Take this sieve in your right hand and hold in a slightly inclined position. Shake it at the rate of about 200 shakes per minute, tapping it gently against the ball of the left hand. To accelerate the process some shot can be placed in the sieve. If more than eight per cent by weight is retained on the sieve the cement should be rejected.

It is agreed that the proportion of very fine material is most important. If a man cares to take the time and is insisting upon a very fine cement, he can use a standard No. 200 sieve and reject a cement that leaves more than twenty-five per cent on the sieve.

Before using the standard screen the cement to be tested should be passed through a No. 20 screen to remove lumps and then be dried at a heat which would boil water.

The reason the test for fineness is recommended first is that the cement will surely be valueless if not finely ground. This test, however, does not indicate a Portland cement except in the hands of an experienced cement tester. Even an expert would not say any cement was either natural or Portland simply after a sieving test. The standard requirements call for a residue for natural cement not exceeding ten per cent on a No. 100 sieve and thirty per cent on a No. 200 sieve.

Rate of Setting.—Natural cement will develop an initial set in ten minutes and a hard set in half an hour. Portland cement should develop an initial set in not less than thirty minutes and a hard set in not less than one hour, nor more than ten hours, in a room varying not more than 10 degrees from a temperature of 62 degrees Fahrenheit, for the rate of setting depends upon the temperature and also upon the amount of moisture.

For this test the operator should wear rubber gloves. Upon a heavy glass or slate plate place the cement in a heap and form a crater in the center. Add about twenty per cent of its weight of water and commence to shovel the cement from the outside into the water until it is all absorbed. This should take not more than a minute. Then knead it vigorously with the hands, like kneading dough, for not more than one minute and a half. Make a ball quickly of this cement and toss it from hand to hand six times, the hands being about six inches apart. Then form it quickly into pats with as little unnecessary handling as possible and with very slight pressure, and no troweling or tamping. These pats are to be about half an inch thick in the center, and come to a fine edge all round. Make them on pieces of perfectly clean glass about four inches square. When it takes a slight pressure to indent the pat with the thumb nail the initial set has commenced.

A better way is to have two pieces of straight wire to use as testing needles. One should be one-twelfth of an inch in diameter and the other one twenty-fourth of an inch. The thick wire should have a four-ounce weight on one end and the other end should be ground perfectly flat. The smaller wire should have a one-pound weight on one end and the other end should be flat. The wires can be seven or eight inches long. A small wooden frame can be whittled with a knife and tacked together with small brads so that the wires can be held perfectly upright in it and move freely. The writer made one out of pieces of cigar box. When the time has passed in which the initial set was to have commenced, put a pat under the frame and gently lower the thick wire to the surface and let it rest there. If it makes an indentation the cement passes the test. If it does not make an indentation, then the cement is too quick setting. If the cement passes the initial set test satisfactorily, try it at the end of the proper time for the final set

with the small wire loaded with the one-pound weight. The pat should not be indented.

The test pats should be stored in moist air during the period of the test. This is readily done by putting them on a screen over a pan of water and covering them with a damp cloth, held above them so it will not touch. The cloth should be damp, and not wet. It should be kept damp.

SOUNDNESS.—Pats should be stored in the moist air for at least twenty-four hours. Then put one in clean water and keep it there for twenty-eight days. Put another in a shady place in ordinary air for the same length of time and observe them at intervals.

Put a third pat in a vessel full of water, entirely immersed. Put a fourth in the vessel above the water so it can be enveloped in steam. Place the vessel on a stove and bring to a boil. Let the water boil five hours, and then remove the vessel and let the pats remain in it until the water again cools to about 70 degrees F.

To pass these tests satisfactorily the pats should remain firm and hard and show no signs of cracking, distortion or disintegration.

The steaming test is not too severe, but the boiling test is very severe. When several cements are tested and all seem good, the one that passes the boiling test best is the better cement. The boiling and steaming tests, however, should only be used when the purchaser wants results in less than twenty-eight days' time. If he can wait twenty-eight days, the fresh water pat will be his best guide for soundness.

The steaming test may cause the rejection of a good Portland cement which has not been sufficiently seasoned.

A pat having attained its permanent set can be broken between the fingers, and if it shows a clean fracture we have an indication that the cement may be good. A ball that has passed the time for permanent set may be dropped from a height of about five feet to the floor, and if it is not broken or cracked the cement may be considered as good.

ADULTERATIONS AND PURITY.—A puzzolan cement made from furnace slag has a very light lilac color. It has no gritty feeling, such as Portland generally has. A pat immersed in water a long time and then broken has an intense bluish-green color in the fresh fracture, which color fades when exposed to dry air.

The color of Portland cement is a bluish gray, and the color

of natural cement may be lighter or darker according to the color of the rock from which made. Color, however, is not always a good indication.

Take about half a teaspoonful of cement and a little more than that amount of water, and make a paste in the bottom of a bowl or cup. Cover with clear muriatic acid poured on slowly, at the same time stirring with a glass rod.

Pure Portland cement will effervesce slightly and give off a pungent gas Gradually a bright yellow jelly will form without sediment.

An excess of lime will cause a violent effervescence, the acid boiling and giving off strong fumes until all the carbonate of lime has been consumed, when the bright yellow jelly will form.

A sand or silica cement will act like Portland cement, but the adulterants will remain at the bottom as a sediment.

If there is any coloring matter present the jelly will not be a clear bright yellow. It is not a defect, but if any coloring is used it is an indication that there is something not altogether right and the manufacturer has tried to conceal it.

Cements which show too much lime or have a deposit indicating too much silica, or any discoloration showing coloring matter has been used, should be rejected.

If adulterated with powdered slag, the test pats will show brown, green and yellow spots and marks when dry.

The writer feels that he should acknowledge here that the acid tests have been taken from "Judson's City Roads and Pavements." The other information follows closely the reports of the United States Engineers, the American Society of Civil Engineers, and the American Society for Testing Materials. We have much to learn yet about cement, but no maker will object to the tests described if he makes good cement, and any firm objecting should be regarded with reasonable suspicion. No good cements will be rejected because of these simple tests, and any intelligent man can make them.

It will be noticed that no mention has been made of the tensile test, without which no series of tests can be said to be complete. The tensile test is the test of the expert manipulator, and cannot be attempted by any man until he has served a long apprenticeship at cement testing.

ANALYSIS OF VARIOUS BRANDS OF PORTLAND CEMENT.

Brand of Cement.	Lime.	Silica	Clay and Iron Oxi'e	Magnesia.	Sulphu'c Acid.	Analysis Made by
Alpha.	63.93	20.68	10.60	2.86	.....	Manufacturer.
Atlas.	62.22	21.48	10.44	2.95	1.03	Department of Public W'ks, Brooklyn, N. Y.
Alpena.	63.35	20.52	10.50	1.93	1.24	Manufacturer's guarantee.
Buckeye.	63.50	22.25	9.75	1.75	.75	Manufacturer.
Colton.	63.05	23.00	11.50	.18	1.63	Adolph New, chemist, Colton, Cal.
Catskill.	63.21	23.44	10.34	1.15	1.25	Manufacturer.
Diamond.	63.40	20.60	12.18	1.44	.79	Superintendent of Construction, U. S. P. O., Clevel'd.
Golden Gate.	60.00	23.10	12.12	1.15	1.84	Adolph New, chemist, Colton, Cal.
Hudson.	62.98	21.60	12.07	1.27	1.33	Manufacturer.
Iroquois.	62.20	23.70	10.39	1.21	1.70	Manufacturer's guarantee.
Ideal.	64.20	23.30	8.40	.72	1.90	Adolph New, chemist, Colton, Cal.
Iron clad.	63.50	21.50	10.50	1.80	1.50	Manufacturer.
Lehigh.	62.96	22.42	9.18	2.76	1.05	Booth, Garret & Blair, Philadelphia, Pa.
Medusa.	64.78	23.30	9.44	.97	1.21	Manufacturer.
Marquette.	64.26	21.80	10.81	1.76	.96	Manufacturer's guarantee.
Napa Junction	61.00	22.50	11.50	1.08	2.00	Adolph New, chemist, Colton, Cal.
Old Dominion.	63.47	20.65	9.69	2.76	1.34	Booth, Garret & Blair, Philadelphia, Pa.
Peninsula.	64.10	22.00	10.50	.60	1.60	Manufacturer.
Saylors.	64.51	19.67	12.34	1.16	....	Manufacturer.
T. A. Edison.	62.71	20.14	10.84	2.34	1.64	Lathbury & Spackman, Philadelphia, Pa.
Universal.	61.92	23.62	11.92	1.78	1.32	Robt. Hunt & Co., Chicago.
Average.	63.10	21.98	10.65	1.61	1.37	

CHARACTERISTIC ANALYSIS OF SLAG OR PUZZOLAN CEMENT.

	Per cent.
Lime	50.22
Silica	24.60
Alumina	13.46
Iron oxide	1.15
Magnesia	2.15
Sulphuric acid	1.35
Loss on ignition	7.07
	100.00

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS BRANDS OF PORTLAND CEMENT.

Brand of Cement.	Twenty-four Hours.		Seven Days.		Twenty-eight Days.		Six Months.		Initial Set in Minutes.	Final Set in Minutes.	Per Cent through No. 100 Sieve.	Test Made by
	Neat.	1 to 3.	Neat.	1 to 3.	Neat.	1 to 3.	Neat.	1 to 3.				
Alpha.	....	....	513	160	699	206	....	....	....	....	.....	U. S. Engineer Corps.
Atlas.	....	....	585	252	760	475	818	497	26	288	98	City Engineer, Youngstown, Ohio.
Alsen (German).	439	....	653	214	703	282	....	....	....	....	80.5	U. S. Engineer, San Francisco.
Alpena.	510	....	704	275	871	379	....	....	155	335	95.3	Department of Public Works, St. Paul, Minn.
Buckeye.	....	....	330	193	518	291	....	....	....	....	.....	Champion Iron Works, Kenton Ohio.
Catskill.	346	....	654	....	736	....	....	....	....	....	86.4	Metropolitan Sewerage Works, Boston.
Castle (Belgian).	235	65	336	121	387	176	....	....	59	290	86	Department of Public Works, Philadelphia.
Colton.	312	110	730	250	900	375	....	....	....	....	.....	Adolph New, chemist, Colton, Cal.
California.	137	....	618	119	719	342	....	....	....	....	86.9	U. S. Engineer, San Francisco, Cal.
Cannon.	....	....	....	212	....	260	....	....	....	....	94	U. S. Engineer, San Francisco, Cal.
Comet.	305	....	573	158	667	230	....	....	....	....	81.7	U. S. Engineer, San Francisco, Cal.
Condor.	165	....	610	162	695	261	....	....	....	....	85.4	U. S. Engineer, San Francisco, Cal.
Chicago AA.	....	....	674	264	775	463	889	606	120	345	94	H. L. Bailey Laboratory, Chicago.
Dexter.	302	....	771	296	841	361	....	....	270	420	99.3	Lathbury & Spackman, New York.
Dragon.	316	107	572	273	744	359	....	....	....	....	96	Illinois Central R. R. Co.
Dykerhoff (German).	249	....	481	252	....	....	....	....	300	....	92	U. S. Engineer Department, Washington.
Diamond.	....	....	682	199	....	....	....	....	50	....	95	Superintendent of Construction, U. S. P. O., Cleveland.
Elk.	300	....	650	200	800	275	900	450	120	300	95	Manufacturer.
English.	330	....	575	....	710	....	....	....	....	....	.....	City Surveyor, Charleston, S. C
Egypt.	....	....	....	159	....	205	....	341	....	....	.....	U. S. Engineer Department, Washington.

Giant	424	87	669	227	719	309	786	329	70	359	90.3	Board of Public Works, Philadelphia.
Germania (German)	202	....	594	198	745	246	....	....	180	....	91	U. S. Engineer Department, Washington.
Golden Gate	260	....	626	283	741	460	....	....	....	....	96.1	U. S. Engineer, San Francisco.
Gillingham	237	....	489	194	52	241	....	....	....	....	....	City Engineer, Los Angeles, Cal.
Green Island (Oriental)	177	....	452	119	564	197	....	....	....	....	84.2	U. S. Engineer, San Francisco.
Hilton's (English)	243	....	625	143	713	209	....	....	....	....	89.9	U. S. Engineer, San Francisco.
Helderberg	250	....	700	302	....	....	....	....	....	....	....	Manufacturer.
Heyen (German)	396	112	543	234	614	288	....	....	108	416	92.3	Board of Public Works, Philadelphia.
Hemmoor (German)	221	84	466	191	502	263	....	....	2	21	95.1	Board of Public Works, Philadelphia.
Hercules	209	47	314	90	425	135	687	265	3	21	77.9	Board of Public Works, Philadelphia.
Henry	164	....	....	159	....	188	....	319	....	....	....	Engineering Department, District of Columb.
Hanover	....	....	....	205	....	244	....	315	....	....	....	Engineering Department, District of Columb.
Hudson	....	....	657	223	736	354	....	....	198	328	92.4	U. S. Engineer, Tuscaloosa, Ala.
Iron Clad	176	....	792	302	819	370	861	496	....	....	....	Aqueduct Commission, New York.
Iola	178	....	834	....	904	....	....	....	150	300	93	Denver Union Water Co.
Iroquois	368	....	688	272	776	336	986	544	180	345	95	Manufacturer.
Ideal	346	....	710	237	847	276	843	497	146	374	97.03	City Engineer, Los Angeles.
Iron Crown	....	....	251	68	478	100	....	....	....	....	79.3	U. S. Engineer, San Francisco.
Josson	235	....	606	202	702	264	....	....	....	....	89.9	U. S. Engineer, San Francisco.
Lehigh	302	....	598	220	685	300	....	....	120	300	95	U. S. Engineer, Buffalo, N. Y.
Lagerdorfer	....	....	436	150	534	223	546	384	165	....	90.3	Colorado Iron Works, Pueblo, Col.
Medusa	....	....	731	196	810	300	....	363	183	378	93.70	U. S Engineer Corps.
Mannheimer (German)	211	74	483	177	585	237	....	....	90	295	93	Board of Public Works, Philadelphia.
Marquette	310	47	799	238	845	367	....	....	....	....	94.5	Illinois Central R. R. Co.
Nazareth	275	90	654	225	765	238	....	....	120	210	97.3	Board of Public Works, Philadelphia.
Napa Junction	225	95	630	208	670	345	....	....	....	....	....	Adolph New, chemist, Colton, Cal.
Owl	154	30	611	209	791	304	937	387	....	....	98	Illinois Central R. R. Co.
Old Dominion	467	....	878	294	....	....	....	....	....	....	93.4	U. S. Engineer Commission.
Omega	....	....	611	202	684	270	....	....	....	....	98.75	Robert Hunt & Co., Chicago.
Peninsula	196	....	354	....	566	....	....	....	....	....	95.05	Watertown Arsenal.
Phœnix	....	....	702	194	679	277	....	....	....	....	....	City Engineer, Minneapolis.

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS BRANDS OF PORTLAND CEMENT—(*Continued*).

Brand of Cement.	Twenty-four Hours.		Seven Days.		Twenty-eight Days.		Six Months.		Initial Set in Minutes.	Final Set in Minutes.	Per Cent through No. 100 Sieve.	Test Made by
	Neat.	1 to 3.	Neat.	1 to 3.	Neat.	1 to 3.	Neat.	1 to 3.				
Porta	....	....	580	209	628	243	....	543	....	....	.....	U. S. Engineer, San Francisco.
Peerless	....	....	451	182	630	253	....	....	105	250	.....	City Engineer, Minneapolis.
Saylor's	....	....	685	177	773	212	....	....	....	....	.....	City Engineer, Minneapolis.
St. Louis "Red Ring"	275	124	790	244	876	300	....	....	....	....	96	Washington University Laboratory.
Steel	128	55	405	224	511	278	....	....	72	127	98.47	City Engineer, Chicago.
Star	437	77	721	219	746	298	....	....	75	299	91.7	Board of Public Works, Philadelphia.
Shifferdicker (German)	272	....	446	175	590	....	....	....	....	....	86.9	City Engineer, Peoria, Ill.
"Sampson" (Canadian)	132	....	428	....	463	....	....	....	....	....	.....	City Engineer, Port Huron, Mich.
Sandusky	162	....	694	....	903	....	....	....	....	....	.....	City Engineer, Port Huron, Mich.
Stettin (Anchor)	....	....	471	168	630	255	....	....	....	....	.....	City Engineer, Youngstown, O.
Struthers	71	....	630	230	709	532	....	....	....	....	98.7	Pittsburg, Carnegie & Western R. R.
Scales (English)	171	....	622	212	795	268	....	....	....	....	99	U. S. Engineer, San Francisco.
Teutonia (German)	....	....	...	241	....	273	....	....	210	300	93.6	U. S. Engineer, San Francisco.
Thomas A. Edison	325	....	676	255	....	331	....	....	120	390	99.8	Lathbury & Spackman, Philadelphia.
Toltec (slag)	196	69	472	154	477	200	....	....	138	345	99	Department of Public Works, Philadelphia.
Universal	559	129	536	248	628	368	937	390	120	420	93.90	Robert W. Hunt & Co., Chicago.
Vulcanite	290	45	748	226	767	287	740	330	108	439	89.90	Board of Public Works, Philadelphia.
Victor ("Invincta")	372	....	486	170	562	226	....	....	....	....	95	Barber Asphalt Co., Long Island.
Wayland	187	42	456	220	565	337	....	....	78	240	88.4	City Engineer, Chicago.
Whitehall	328	79	855	339	991	459	....	....	180	360	95.75	U. S. Navy, Annapolis, Md.
White's (English)	....	....	642	277	836	412	....	....	60	540	94	R. W. Hunt & Co.

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS NATURAL OR ROSENDALE CEMENTS.

Brand of Cement.	Twenty-four Hours.	Seven Days.		Twenty-eight Days.		Six Months.		Percentage thro'h No. 100 Sieve.	Test made by
	Neat.	Neat.	1 to 2.	Neat.	1 to 2.	Neat.	1 to 2.		
Akron Star-brand........	172	259	......	352	......	475	......	......	City Cement Inspector, Philadelphia, Pa.
"Banner" Louisville.	104	113	70	160	140	......	......	88	Chicago Drainage Canal Board.
Beaches...............	115	190	47	367	93	......	......	80	U. S. Engineer, Fort Delaware.
Ft. Scott "Double Star.".	46	137	......	327	......	......	......	......	Manufacturer.
Improved Anchor.	164	271	......	378	......	515	......	......	City Cement Inspector, Philadelphia, Pa.
Louisville Star.	79	135	63	210	124	348	241	76.2	Osborn Engineering Co., Cleveland.
Lehigh Improved.	145	235	......	352	......	440	......	......	City Cement Inspector, Philadelphia, Pa.
Milwaukee.	97	141	......	259	......	397	......	93	Company's Laboratory.
Mankato.	142	179	......	267	......	......	......	......	City Engineer, St. Paul, Minn.
Norton's Rosendale.	107	141	36	......	......	......	......	......	Northern Central R. R. Co.
Northern Hydraulic......	200	......	100	300	200	......	400	96	Manufacturer's guarantee.
Shield Improved.	170	239	127	298	220	......	......	95	Booth, Garret & Blair, Philadelphia.
Utica.	......	207	152	230	225	311	302	91	Sanitary District, Chicago.
Union Improved.	155	209	......	316	......	446	......	......	City Cement Inspector, Philadelphia.

PART II.

CONCRETE, AGGREGATES AND SAND, MIXING CONCRETE, STRENGTH OF CONCRETE, SPECIFICATIONS FOR CONCRETE, COMPOSITION OF CONCRETE, NOTES ON CEMENT AND CONCRETE.

Concrete.—Concrete is a mixture composed of broken stone, gravel, or similar material held together by cement mortar. The theory of concrete is that enough cement mortar should be used to fill all the voids between the stones.

On large engineering works, the proportions of cement, sand, and broken stone or gravel should be accurately determined and specified. For general purposes it is possible to state approximate proportions, as the sand, broken stone, and gravel vary in size and proportions of voids according to their source and preparation.

The proportion of sand and stone must also be adapted to the character of the work in which the concrete is to be used and the strength required.

Concrete Construction.—Concrete was the most important of all the building materials used by the Romans, and the developments of the past few years have brought about changes until it is now recognized as one of the most important materials used at the present time.

A test as to the durability of concrete is found in the Pantheon at Rome, which was built by Agrippa, 27 B.C., nearly 2000 years ago. The circular walls are about 20 feet in thickness, and the roof is a hemispherical cement concrete dome with a 30-foot opening in the top and spanning in the clear 142 feet 6 inches. This is the most remarkable instance in the world's

history, showing the great strength and durability in cement-concrete construction.

Concrete construction is usually done by building wood forms or moulds and ramming them full of concrete, either solid or with hollow walls.

It is advisable to wet the concrete several times a day for several days after it has been put in place, to prevent it drying too fast. In building forms for foundations, walls, etc., care must be taken to provide chases and openings for all pipes, etc., and where any wood is to be fastened to the concrete, to build in bolts with the nut end sticking out from the face of the wall a sufficient distance to bolt up the woodwork.

Concrete is one of the best and most reliable of building materials when mixed and put in place in a proper manner; where there have been failures in concrete construction it has generally been due to one of the following causes: Bad centering and forms, bad material, poor mixing, insufficient ramming or insufficient and poor reinforcement.

Aggregate.—The aggregate for concrete is usually broken stone, gravel, or cinders, or two or all of them combined. Along the seashore and rivers gravel is often used because it can be obtained much cheaper than the broken stone, and makes very good concrete, but on account of the smooth surface of the stones does not make quite as strong a concrete as broken stone, which, with its rough angular surfaces and corners, causes the mortar to take a better hold.

Broken-stone Aggregate.—The best stone for concrete consists of angular pieces, varying in size from $\frac{1}{2}$ to 2 inches. An aggregate made up of stones of various sizes does not require as much sand and cement, the voids not being so large as if the stone were all of the larger size. The stone should be clean and have a rough surface.

When broken stone is used it should be cleaned from dust and dirt, by passing it over a $\frac{3}{8}$-inch mesh sieve. This is usually done at the crusher. The best results are obtained from strong, hard, durable rocks, which fracture into sharp angular fragments, such as granite, trap-rock, or limestone. Soft, porous, friable rocks, or rocks of a slaty fracture, should be avoided. Dust in crushed stone weakens the concrete. Aggregate for reinforced concrete should not be over $\frac{3}{8}$ inch in diameter.

The voids in broken stone run from about 38% to 55%, depending on the size and amount of small stone contained.

Broken stone from	1″ to 2″	contains about	50%	voids
" " "	½″ to 1″	" "	53%	"
" " "	⅜″ to ½″	" "	52%	"
" " "	0″ to 2″	" "	45%	"
" " "	0″ to 1″	" "	43%	"

VOIDS IN LOOSE BROKEN STONE.

Authority.	Per Cent Voids.	Remarks.
Sabin	49.0	Limestone, crusher run after screening out ⅛ in. and under.
"	44.0	Limestone (1 part screenings mixed with 6 parts broken stone).
Wm. M. Black	46.5	Screened and washed, 2 ins. and under.
J. J. R. Croes	47.5	Gneiss, after screening out ¼ in. and under.
S. B. Newberry	47.0	Chiefly about egg size.
H. P. Boardman	39 to 42	Chicago limestone, crusher run.
"	48 to 52	" " screened into sizes.
Wm. H. Hall	48.0	Green River limestone, 2½ ins. and smaller, dust screened out.
"	50.0	Hudson River trap, 2½ ins. and smaller, dust screened out.
Wm. B. Fuller	47.6	New Jersey trap, crusher run, ⅙ to 2.1 ins.
Geo. A. Kimball	49.5	Roxbury conglomerate, ½ to 2½ ins.
Myron S. Falk	48.0	Limestone, ½ to 3 ins.
W. H. Henby	43.0	" 2-in. size.
"	46.0	" 1½-in. size.
Feret	53.4	Stone, 1.6 to 2.4 ins.
"	51.7	" 0.8 to 1.6 in.
"	52.1	" 0.4 to 0.8 in.
A. W. Dow	45.3	Bluestone, 89% being 1½ to 2½ ins.
"	45.3	" 90% being ⅙ to 1½ in.
Taylor and Thompson	54.5	Trap, hard, 1 to 2½ ins.
" " "	54.5	" " ½ to 1 in.
" " "	45.0	" " 0 to 2½ ins.
" " "	51.2	" soft, ¾ to 2 ins.
G. W. Chandler	40.0	Canton, Ill.
Emile Low	39.0	Buffalo limestone, crusher run, dust in.
C. M. Saville	46.0	Crushed cobblestone, screened into sizes.
T. Appleton	43.7	½ to 2 ins.

Broken stone being angular does not compact so readily as gravel, and shows a higher percentage of voids when the fragments are uniform in size and shoveled loosely into a box; but the voids, even then, seldom exceed 52%.

The following records of actual tests will indicate the range of void percentages:

Prof. S. B. Newberry gives the voids in Sandusky Bay gravel, ¼ to ⅛ in. size, as being 42.4% voids; ¼ to 1–20 in. size, 35.9% voids.

Mr. William H. Hall gives the following tests on mixtures of Green River, Ky., blue limestone and Ohio River washed gravel:

Stone.		Gravel.	Voids in Mixture.
100%	with	0%	48%
80	"	20	44
70	"	30	41
60	"	40	38½
50	"	50	36
0	"	100	35

The stone passed a 2½-in. screen and the dust was removed by a fine screen. The gravel passed a 1½-in. screen.

The voids in mixtures of Hudson River trap-rock and clean gravel, of the sizes just given for the Kentucky materials, were as follows:

Trap.		Gravel.	Voids in Mixture.
100%	with	0%	50%
60	"	40	38¼
50	"	50	36
0	"	100	35

Mr. H. von Schon gives tests on a gravel having 34.1% voids as follows:

Retained on 1-in. ring	10.70%
" ⅜-in. ring	23.65
" No. 4 sieve	8.70
" No. 10 sieve	17.14
" No. 20 sieve	21.76
" No. 30 sieve	6.49
" No. 40 sieve	5.96
Passed No. 40 sieve	5.59
" 1½-in. ring	100.00

Gravel Aggregate.—Gravel makes a very good aggregate for concrete work. It should be of various sizes ranging from ½ to 2 inches; should not contain much clay, and no vegetable or earthy matter, and if very dirty it should be washed before using.

For cellar floors gravel is often preferred to broken stone for an aggregate, as the gravel being a survival of the hardest stones, it is more nearly waterproof than some crushed stone.

Gravel from ½″ to 2″ contains about 35% voids.

Cinder aggregate is usually used for concrete fireproof floor work. It is used on account of its being lighter than other aggregates.

A cinder aggregate should really contain very little cinder, but should be nearly all clinkers which will pass through a 1-inch mesh sieve, and if very dirty, they should in addition be passed over a $\frac{3}{8}$-inch mesh sieve. They should not contain more than 5 per cent of ash or unburned coal. Specifications usually call for rolling-mill slag or good, clean, crushed vitrified clinkers, and such materials should always be used, as the ordinary cinders are not fit for fireproof work. The large clinkers can be broken, as described on page 147.

Crushed Slag Aggregate.—Crushed furnace slag is often used as an aggregate for fireproofing and makes good concrete. It is lighter than stone and strictly fireproof.

The voids in slag are about the same as in broken stone.

Sand for Concrete.—Sand should be clean, coarse, and sharp. A quartz sand gives the best results. Loamy sand or that containing much clay should not be used; it will give poor results and retard the set. Organic matter and dirt are objectionable in any sand. A very fine sand or gravel is not good, as it weakens the work. A very coarse sand gives the greatest strength in concrete, but when the proportions of sand exceed 2 parts to 1 of cement, a sand of mixed grains, fine to coarse, with the coarse predominating, is preferable. as the fine sand helps to fill the voids in the coarse sand and makes a more dense and less absorbent mortar.

The voids in sand are about as follows:

Bank sand	30%
River sand, fine	30
" " coarse	40
" " fine to coarse	32
Lake or ocean sand, coarse	40

Proportioning Materials for Concrete.—A simple way of determining the proper proportions for concrete is as follows:

Take a water-tight barrel and bore a hole in the bottom. In this fit a long wooden plug. Fill the barrel with the crushed stone and then pour in water until it over flows; draw the water off in buckets and measure. The quantity of water represents the voids between the stone to be filled with mortar.

Now empty out the stone from the barrel; pour back the water and mark the level on the side; then draw the water off; fill with sand to the mark, and this will determine the amount of sand to be used. Lastly, pour in enough water to come up to the level of the sand, and the amount used indicates how much cement is needed to fill the voids in the sand. To the above proportion of sand and cement add respectively ten per cent and the correct amounts of cement, sand, and broken stone will have been found.

Wet and Dry Concrete.—There is quite a difference of opinion among engineers and architects as to just what amount of water should be used in mixing concrete to get the best results. Some claim that it should be mixed with as little water as possible, others think that a very plastic or wet concrete is best. It is the opinion of the author that either, according to the conditions under which it is to be used is better than the other. For instance, in a large foundation or any place where the concrete can be spread in thin layers and where no trouble will be experienced in ramming, a mixture that, when rammed enough to make it a solid and compact mass with no voids, and which at the end of this ramming shows just a little water at the top, will make as good a concrete as it is possible to obtain. On the other hand, in narrow walls or foundations, between beam grillage, and all places where any difficulty will be had in ramming, then a wet concrete will work the best.

The author has used concrete in such places, mixed so it would just carry the man ramming, and which when he walked or tamped on it, caused it to "quake," and which gave excellent results, and contained no cavities. Where a concrete is to be made water-tight a mixture of this kind will give the best results. Very often workmen will go to the extreme and use too much water, making the concrete too wet. It should just show up mushy when tamped or worked into place and stiff enough so the aggregate will be held in place. If too wet the aggregate will settle to the bottom before the cement sets, thus making a strata of poor concrete at the bottom of each layer deposited.

Tests have been made which show while the dry concrete becomes much stronger in a short period of time, the wet mixture if allowed to harden for a long period will ultimately become stronger than the dry mixture.

Where a wet concrete is to be used the forms or moulds should be nearly water-tight.

MEASURING MATERIALS FOR CONCRETE.—The ordinary unit of measurement used by workmen for measuring the materials for concrete is the wheelbarrow. This method, if care is exercised, is exact enough for all work, but the workmen are liable to become careless and not fill all barrows equally.

The first step is to ascertain just how much or how many sacks of cement a barrow will hold; then it can be readily figured how many barrow loads of each material is required for a batch of concrete.

A more exact method is to use a barrel with both heads out, setting the barrel up on the mixing platform or pile and filling it with the material, then lifting the barrel, allowing the material to run out on the platform or pile. Set the barrel up and fill it again until each material has been measured. First measure the aggregate, level the pile off and on top measure the sand and on top of this put the cement.

A method the author uses is bottomless boxes, set one on top of the other, and which will be described on a following page.

MIXING CONCRETE.—This is another point in concrete work where engineers and architects differ in opinion, some even preferring hand-mixing to that done with a machine. There are a number of ways or methods employed for mixing concrete by hand, and they will nearly all give good results providing enough labor is expended.

A good rule for mixing concrete by hand is to mix it enough and once more for luck.

A method which the author has used for hand-mixing and which gave excellent results as to cost of labor and result of mixing is described as follows:

Make a tight platform about 30 feet long and 14 feet wide. On one end of this platform mix the sand and cement dry in the following manner: Have a bottomless box of sufficient size and depth to measure the exact proportion of sand, place it on the platform as shown at *A*, Fig. 1, and fill it with sand, using a straight-edge to strike it level full. On top of this set another bottomless box of the correct depth to measure the correct proportion of cement and fill it in like manner; now lift the two boxes and thoroughly mix the sand and cement until it is of a uniform color.

While the cement and sand are being mixed by part of the "gang," let the rest prepare the aggregate. Place a bottomless box on the platform close to the pile of cement and sand as shown by *B*, Fig. 1, the box to be of a depth to measure the

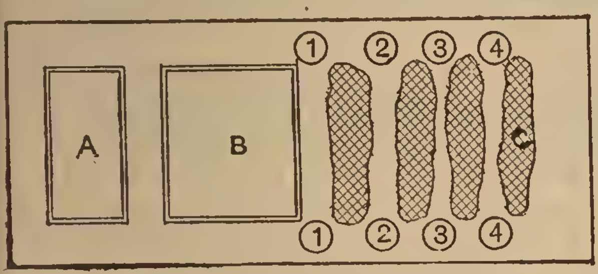

FIG. 1.

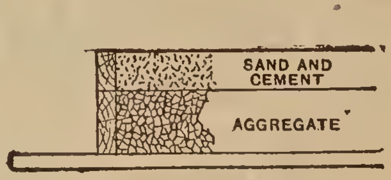

FIG. 2.

aggregate; fill it level full and set on top another box to measure the combined cement and sand; fill the latter level full, as shown by Fig. 2; now remove the boxes and the mass is left in a flat pile with the cement and sand spread uniformly over the aggregate. Now let two men, as 1, 1, Fig. 1, start turning the pile toward the vacant end of the platform, and as they turn keep the new pile about the same width and depth as the one made by the boxes.

After they have started turning start two more men as shown at 2, 2, giving the second turning; but as it is turned and spread in the pile have a man with the hose and sprinkler (or a good plan is to tie the nozzle of the hose on a shovel-blade so the blade will spray the water) and wet the mass as it is spread in the pile. Then give it two more turnings by men at 3, 3 and 4, 4, and when it reaches the pile *C*, as shown in Fig. 1, it is thoroughly mixed. With a little experience the man with the water will be able to regulate it so that each batch will have about the same amount of water.

The author has also used three boxes as described, on top of each other, one for the aggregate, one for the sand, and one for the cement; then turning and mixing the mass as described, it gave a very uniform mixture. In mixing by hand the men should be provided with long-handled, square-bladed shovels, as they can reach the centre of the pile better and will not tire themselves as with a short-handled shovel. In large work the concrete can be mixed very rapidly as described; as one batch is being finished another one can be got ready, and thus a continuous stream of concrete can be turned out. The author

has seen concrete mixed in this way in competition with a machine where the amount mixed by hand in a day was equal to that done by the machine with the same amount of labor.

On small work, where it would not pay to go to the trouble as described above, a good method is to mix the sand and cement dry, then add the water, making a wet mortar, spread this out and add the aggregate which has already been wet and washed; now turn and mix until a uniform mass is obtained.

For the mixing of concrete by hand at the U. S. Post-Office, Court House, and Custom-House at Wheeling, W. Va., the following was specified: "The cement and sand will first be thoroughly mixed dry and enough water added by fine sprinkling to form a stiff plastic paste, and, after the gravel has been thoroughly drenched with water, it will be added to the mortar and the whole mixed to a proper uniform consistency. The proportions are intended to secure a concrete in which every particle of sand is enveloped by cement and all voids in the gravel filled with mortar, but this result must be obtained to the satisfaction of the superintendent. The mixing will be done on a water-tight platform with raised edges, the cement spread first, and no batch shall contain more than one barrel of cement."

Proportions and Strength.—The proportion of the mortar to the aggregate should be such that it will a little more than fill all the voids of the aggregate, the strength of the concrete depending a great deal on the proportion of sand to the cement.

For all ordinary purposes, such as heavy foundations, machinery foundations, reservoirs, cisterns, retaining-walls, sub-surfaces of sidewalks, cellars, and street-paving, 1 part of cement, 2 or 3 parts of sand, with 5 parts of broken stone, will give the best results; for footings and subwork 1 part of cement, 3 parts of sand, and 7 parts of broken stone will give excellent results.

Care should be taken to see that the proportious are such that the mortar will fill all the voids in the aggregate, and the mass will tamp solid. The proportion of cement and sand to the aggregate depends a great deal on the nature of the aggregate; if it is of coarse stone with large voids then it will require more mortar to fill them than if the aggregate was of a

finer stone or gravel. To determine the voids in any aggregate, take a box containing a cubic foot and fill it with the aggregate, which should already be soaked with water, then pour water in the box until it is full; now pour off the water and measure it, which will show the voids contained in a cubic foot of the aggregate.

A good method of determining the voids in concrete materials is to fill a box of exactly 1 cubic foot capacity, or a convenient fraction thereof, with the substance and weigh the contents. A solid block of quartz or limestone, measuring exactly 1 cubic foot, would weigh 165 pounds; a cubic foot of sand, gravel, or broken stone considerably less than the latter amount, and the difference will represent the voids. For example, if 1 cubic foot of gravel weighs 95 pounds, the difference is $165-95=70$. The percentage of voids in then $70\times100\div165=42.4$.

The following table shows the percentage of voids found in some common concrete materials:

Sand, not screened..........	32.3 per cent	voids
Gravel, $\frac{1}{4}$- to $\frac{1}{8}$-inch..........	42.4 "	"
Broken stone, 1- to 2-inch....	47.0 "	"

Mixed materials, which contain the greatest variety of sizes from fine to very coarse, will be found to have the least voids. With any two materials, one fine and one coarse, there is one mixture, and only one, which will give the greatest possible density. This may be determined by calculation; for example, taking the gravel given above, since it contains 42.4 per cent voids, we must fill these by adding sand to the amount of 42.4 per cent of its volume. For this we require 42.4 measures of sand to 100 measures of gravel, or 1 to $2\frac{1}{3}$. For the stone, 47 measures to 100 will be required, or 1 to 2.13. With mixed materials, such as are generally met with in practice, in which no sharp division between sand and gravel can be made, practical test will be found more satisfactory than calculation. The sand and gravel or stone should be mixed in the calculated proportion, and also in other proportions, and the weight per cubic foot of each mixture taken, until that giving greatest density is found. With favorable materials it will be found possible to make a mixture weighing 140 pounds per cubic foot, corresponding to 15 per cent voids. If the greatest weight obtainable is less than this, the materials are not the best.

The proportion of cement to be used depends upon the per cent of voids in the mixture of sand and gravel or stone, and also upon the purpose for which the concrete is required. In general it may be said that an amount of cement sufficient to fill the voids in the mixture will give a first-class concrete. With mixed materials weighing 140 pounds per foot and containing 15 per cent voids, cement to the amount of 15 per cent, by measure, or 1 to $6\frac{2}{3}$, will theoretically be required. Greater compression strength may be obtained by increasing the proportion of cement, and for the foundations of engines or other heavy machinery as high a proportion as 1 to 5 may well be used. On the other hand, for foundations of buildings, filling of abutments, and other purposes requiring less strength, mixtures of 1 to 10 or 1 to 12 will be found fully satisfactory.

It should be remembered that the strength of the concrete will depend on its density. A mixture of cement and sand, 1 to 3, will usually be found weaker than a 1 to 7 mixture, rightly proportioned, of cement, sand, and gravel or stone. Mixtures of cement and sand are greatly *strengthened* by the addition of a suitable amount of coarse material, though the proportion of cement is thus decreased. It is, therefore, well worth while to give careful study to the concrete materials which it is proposed to use.

The following table, showing the result of tests of cement mortar of different proportions and age, was made at the United States Arsenal, Watertown, Mass. The cement used was Peninsula Portland cement.

COMPRESSIVE STRENGTH OF PORTLAND-CEMENT MORTAR IN POUNDS PER SQUARE INCH.

Age in			Neat.	1 Cement, 1 Sand.	1 Cement, 2 Sand.	1 Cement, 3 Sand.	1 Cement, 4 Sand.
Air.	Water.	Air.					
7	......	......	4970	2850	1370	....	473
1	6	......	6260	2880	1440	....	557
30	......	......	6140	3400	1490	....	656
1	29	......	8870	4680	2750	....	950
92	......	......	6080	3410	....	....	....
1	91	......	9560	....	....	....	....
1	91	2	....	7570	....	....	....
1	90	2	....	....	4990	....	....
93	......	......	....	....	2635	....	....
100	......	......	....	....	....	....	1030
101	......	......	....	....	....	1510	....
1	96	4	....	....	....	3140	....
1	95	4	....	....	....	....	1970
1	70	......	....	....	....	2570	....

Taylor and Thompson in "Concrete, Plain and Reinforced," give the safe strength of concrete as follows:

SAFE STRENGTH OF PORTLAND CEMENT CONCRETE IN DIRECT COMPRESSION.

Proportions.	Pounds per Square Inch.	Tons per Square Foot.
1 : 2 : 4	410	29
1 : 2½ : 5	360	25
1 : 3 : 6	325	23
1 : 4 : 8	260	18

With a large mass foundation take values one-eighth greater.
With a vibrating or pounding load, take one-half these values

WORKING STRENGTH OF CONCRETE AS ALLOWED BY THE BUILDING CODES OF VARIOUS CITIES.

Proportions of Mixture.				Working Strength (Compression) per Square Inch of Section.				
Portland Cement	Rosendale or Equal Cement.	Sand.	Broken Stone.	New York, 1902.	Chicago 1905.	Philadelphia, 1902.	Cleveland, 1904.	Nat. Board of Fire Underwriters, 1905.
1	....	2	4	230	173	208	222	230
1	....	2	5	208	173	208	194½	208
	1	2	4	125	....	....	111	125
	1	2	5	111	....	....	83⅓	111

RESULTS OF TESTS MADE TO DETERMINE THE STRENGTH OF CONCRETE WHEN CEMENT IS MIXED WITH SAND, CLAY, AND LOAM IN VARYING PROPORTIONS.*

The cement was "Double Anchor," German brand, the sand standard quality; the clay was taken from the cutter of a dredge working in Galveston channel; the loam was heavy black soil from the mainland. Both loam and clay were thoroughly pulverized, free apparently from all vegetable matter and sand, and sifted to remove lumps. All briquettes were made from one sample on the same day, under same conditions.

* Extract from report on Defenses of Galveston, Tex., by officer in charge, Capt. Edgar Jadwin, Corps of Engineers, to Chief of Engineers. Printed in the Report of the Chief of Engineers for 1905.

The clay acted so unsatisfactorily during the working of the 25% batch that no more briquettes were made for this particular test, but the loam was continued to 40%.

Tensile Strength Test Completed Aug. 1, 1904.

	Old Shipment.					
	7 Days.			28 Days.		
	No. 1. Lbs.	No. 2. Lbs.	No. 3. Lbs.	No. 1. Lbs.	No. 2. Lbs.	No. 3. Lbs.
Sand and cement, 3 to 1 . .	170	166	190	240	240	260
	180	168	191	245	236	265
Sand with 5% loam	187	. . . . . .	. . . . . .	250		
	183	. . . . . .	. . . . . .	245		
Sand with 10% loam	. . . . . .	165	. . . . . .	. . . . . .	241	
	. . . . . .	175	. . . . . .	. . . . . .	250	
Sand with 15% loam	. . . . . .	. . . . . .	203	. . . . . .	. . . . . .	275
	. . . . . .	. . . . . .	210	. . . . . .	. . . . . .	275

Tensile Strength Test Computed Feb. 5, 1904. for Six Months' Breaks.

	New Shipment.—Breaks.			
	7 Days. Lbs.	28Days. Lbs.	3 Mos. Lbs.	6 Mos. Lbs.
Sand and cement, 3 to 1	210	316	350	339
	207	337	329	346
5% clay	220	356	341	340
	218	343	336	334
5% loam	208	367	309	316
	201	359	321	320
10% clay	210	321	329	327
	213	330	336	334
10% loam	200	369	320	330
	207	365	329	331
15% clay	200	296	270	225
	208	301	260	220
15% loam	202	365	321	319
	205	368	328	315
20% clay	184	262	250	200
	189	267	258	216
20% loam	220	370	250	230
	216	372	241	225
25% clay	172	240	230	175
	166	251	216	160
25% loam	221	373	239	222
	218	375	248	217
30% loam	220	361	256	210
	225	350	250	216
35% loam	205	300	239	220
	198	306	248	212
40% loam	198	290	240	198
	189	279	232	213

The following tests on the crushing strength of concrete were made by Lathbury & Spackman, Philadelphia, Pa.

REPORT ON CRUSHING STRENGTH OF SIX-INCH CUBES.

Composition.	Age.	Average Crushing Strength, Three Cubes to Each Test.
1 part Lehigh Portland cement 2 parts sand 4 parts crushed stone	7 days 30 " 90 "	36,270 lbs. 85,810 " 98,087 "
1 part Lehigh Portland cement 3 parts sand 6 parts crushed stone	7 days 30 " 90 "	28,433 lbs. 62,003 " 73,073 "
1 part Lehigh Portland cement 4 parts sand 8 parts crushed stone	7 days 30 " 90 "	22,687 lbs. 48,790 " 61,230 "

The following report of U. S. Engineer Corps gives the result of tests made with Atlas Portland cement in concrete of different proportions.

OFFICIAL REPORT U. S. GOVERNMENT ENGINEERS ON ATLAS PORTLAND CEMENT.

REPORT OF TESTS OF CRUSHING STRENGTH OF ONE-FOOT CUBE OF CONCRETE.

Made by Capt. Wm. M. Black, Corps Engineers, U.S.A., Washington, D.C. Dec. 1, 1897.

No.	Composition.	Age.	Crushing Strength.
7	1 part Atlas cement 2 parts sand 6 parts broken stone	10 days 2 months 6 " 12 "	137,500 lbs. 255,000 " 320,000 " 440,000 "
11	1 part Atlas cement 2 parts sand 3 parts gravel 3 parts broken stone	10 days 2 months 6 " 12 "	95,000 lbs. 232,500 " 280,000 " 405,000 "
8	1 part Atlas cement 2 parts sand 2 parts gravel 4 parts broken stone	10 days 2 months 6 " 12 "	32,500 lbs. 267 500 " 295 000 " 390,000 "

The following are the requirements of the U. S. Navy for tensile tests of Portland cement.

TENSILE STRENGTH.—The neat briquettes, prepared as specified, shall stand a minimum tensile strain per square inch, without breaking, as follows:

For 12 hours in air and 12 hours in water........... 200 lbs.
" 1 day " " " 6 days " " .... 550 "
" 1 " " " " 27 " " " .... 650 "

The mortar briquettes, prepared as specified, shall stand a minimum tensile strain per square inch, without breaking, as follows:

After 12 hours in air and 12 hours in water........... 150 lbs.
" 1 day " " " 6 days " " .... 200 "
" 1 " " " " 27 " " " .... 250 "

CRUSHING STRENGTH OF NATURAL-CEMENT CONCRETE.—Report of crushing tests made by the U. S. Government at the Watertown Arsenal, Watertown, Mass., of concrete blocks made with Akron Star Brand Natural Cement, the blocks being cubes, 12 inches each way, thus making each block one cubic foot of concrete. The strength given is the average of three blocks of each kind.

Cement.	Sand.	Gravel.	Broken Stone.	Thirty Days, Lbs.	Seven Months, Lbs.	One Year, Lbs.
1 part	1½ parts	0 parts	4 parts	215.835	321.833	432,333
1 "	3 "	0 "	7½ "	150.367	290.167	306.667
1 "	2 "	3 "	4 "	161.200	319.867	329,500
1 "	2 "	7 "	0 "	110.267	239.533	264,700
1 "	2½ "	8 "	0 "	109.467	225,733	232,733

PROTECTION OF STEEL BY CONCRETE.—By tests made, it has been found that steel or iron when properly covered with cement mortar or concrete is perfectly protected from rust, but the mortar must have contact with and cover all surfaces of the steel. The concrete should be made wet enough so that it can be tamped close around the steel. With cinder concrete it should be thoroughly mixed and wet enough so that the cinders will not absorb all the water before the cement is tamped in place.

The following conclusions were arrived at by Mr. C. L. Norton after making a number of tests as to the value of cement mortar and concrete to protect steel from rust:

"(1) Neat Portland cement, even in thin layers, is an effective preventive of rusting.

"(2) Concretes to be effective in preventing rust must be dense and without voids or cracks. They should be mixed quite wet when applied to the metal.

"(3) The corrosion found in cinder concrete is mainly due to the iron oxide or rust in the cinders and not to the sulphur.

"(4) Cinder concrete, if free from voids and well rammed when wet, is about as effective as stone concrete in protecting steel.

"(5) It is of the utmost importance that the steel be clean when bedded in concrete. Scraping, pickling, a sand-blast, and lime should be used, if necessary, to have the metal clean when built into a wall."

Fred. von Emperger, C.E., describes rods embedded in concrete under water for four hundred years coming out free from rust. W. G. F. Triest dug a wrench out of a concrete bridge pillar, which was free from rust after being embedded for twenty-two years. E. L. Ransome partly embedded some hoop iron in concrete blocks and left them exposed to sea air for many years. When the exposed iron had disappeared in rust, the blocks were cut open and the iron was found to be free from rust. The safety of the Chicago buildings supported by steel grillages depends on the concrete protecting this steel from corrosion. The wire netting in Monier pipe, after thirteen years' service, has been found in the same condition as when embedded. Professor Bauschinger has found an adhesive action between steel and cement mortar greater than the tensile strength of the latter.

During the construction of the Rapid Transit subway in New York City, a sidewalk laid in 1883 by Matt Taylor was torn up, and embedded in the concrete were found a number of steel rods which were in perfect condition after having been in the concrete for a period of nearly seventeen years.

Depositing Concrete.—Concrete should be deposited just as soon as mixed; it should be spread in layers about 8 inches thick and rammed solid, and each succeeding layer put on before the one below has set; in this way the concrete becomes one mass, and a solid block is the result.

The concrete should never be dumped from any height, but should be deposited with a shovel. If it is dumped any distance the stone aggregate will become separated from the mortar.

Where any concrete is to be put on top or against any that

is already set the surface of the concrete already in place should be coated over with a thick cement grout, as this will insure the two masses adhering together.

SPECIFICATIONS FOR CONCRETE.

As a guide for workers in concrete the following extracts from specifications, which are considered very good are given.

The following regarding concrete was taken from the specifications prepared by the Reclamation Service of the United States Geological Survey.

CONCRETE.—This includes all concrete in place, except pressure pipes.

The cement will be furnished by the Secretary of the Interior. The concrete to be used on all of the structures on this canal will be composed of Portland cement, sand, and gravel, or broken stone, in the proportion of one barrel of cement, in the packed condition in which it is sold, to seven full barrels of the same size, of the aggregates when mixed together. To facilitate the work experiments will be made by the contractor with the carriers, whether wheelbarrows, boxes, or cars, used by him, so that this proportion of cement to aggregates may be maintained as nearly as possible, and the engineer will supervise these experiments and fix said proportion for the kind of carrier used at each piece of work. He will also make experiments with the aggregates themselves so as to get the most compact mass that can be made from them, and for such experiments no extra allowance will be made to the contractor. If the cement comes in sacks, then 380 pounds net of cement will constitute a barrel, and any ordinary cement barrel open at one end containing not more than 3.7 cubic feet will be used for measuring the aggregates. If broken stone is used, it must be hard and compact, and satisfactory to the engineer. The entire product of the crusher will be taken, provided there is not more than ten (10) per cent of the volume composed of dust or screenings. All of the rock must be of such sizes as will pass through a screen with two (2) inch square mesh. If gravel is used it must be clean, hard, and heavy, having at least a specific gravity of 2, and screened into three different sizes. None of the gravel is to exceed 2 inches in diameter. The mixture of such sizes will be made in the proportion fixed by

the engineer. A promiscuous mixture of sand and gravel will not be accepted. The sand must be clean and sharp and free from any clayey matter.

The mixing of the concrete, if hand labor is used, will be done in the following manner: A tight floor of either planks or sheet iron will be used for the mixing in all cases. The sand must be dry, and will first be piled on the floor with the cement in the proper proportions; the mass will then be shovelled over as many times as are necessary to make a thorough mixture of sand and cement; sufficient water will then be added to make a stiff mortar and the mass shovelled over twice or more, as may be necessary. The stone or gravel, which should be well wet, will then be added, and the entire mass shovelled over twice or more before shovelling into the carriers. This mixing must be done to the satisfaction of the engineer. If the mixing is done by machine, the latter will be subject to approval by the engineer. If at any time the machine fails to perform the mixing in a manner satisfactory to the engineer, it must be made satisfactory or removed, and another machine substituted, or mixing by hand resorted to. . . .

In all concrete walls over 2 ft. thick hard boulders, or fragments of hard sound rock, not exceeding 1 ft., or less than 6 ins., in any dimension, may be placed by hand in the soft concrete, provided no such stone comes nearer than 2 ins. to the exterior surface of the wall, or to any other boulder or stone so placed. . . . All concrete shall be well tamped, if put in dry, with heavy tamping-bars, until moisture appears on the surface; and, if wet, with suitable bars and shovels, so that porosity and rough surface may be avoided. Concrete will be used "wet" wherever practicable, and "dry" only when the nature of the work renders its use unavoidable.

Mortar.—The following, regarding proportions of mortar, is taken from Cooper's "General Specifications for Foundations and Substructures":

"24. Cement mortar will be made by thoroughly incorporating the cement and sand in the following proportions, viz., one barrel of 300 pounds of natural cement and 12 cubic feet of sand, or one barrel of 375 pounds of Portland cement and 16 cubic feet of sand, with sufficient water to obtain the proper consistency.

"28. For foundations below the surface of the ground where the concrete will not be exposed to the action of running water

or to weather, the concrete shall be made of the following proportions: For each barrel of natural cement, 12 cubic feet of sand and 24 cubic feet of broken stone or coarse gravel.

"29. For monolithic piers and abutments, for cylindrical and wooden box piers, and for foundations where there is a liability to the action of running water or where the bottom is soft or of unequal firmness, the concrete shall be made of the following proportions: One barrel of Portland cement, 10 cubic feet of sand and 20 cubic feet of broken stone or coarse gravel."

MORTAR, GROUT, AND CONCRETE.—The following specifications were prepared for the concrete work of the retaining-walls of the Pennsylvania R. R. Terminal Station, New York City:

In proportioning materials for mortar, grout, and concrete, 1 volume of cement shall be taken to mean 380 lbs. net. One volume of sand or broken stone shall be taken to mean $3\frac{1}{2}$ cu. ft. packed or shaken down. Sand and broken stone shall be measured in barrels or rectangular boxes. Measurements in wheelbarrows will not be permitted.

In preparing mortar, the specified amounts of cement and sand shall first be mixed dry to a uniform color. The water shall be added in such a manner as not to wash out any of the cement and the mixing proceeded with until the mortar is thoroughly mixed and of uniform consistency. The proportions of cement and sand will generally be 1 to $2\frac{1}{2}$ by volume, but when the work is wet, the proportion of sand shall be reduced as required by the engineer.

Grout will generally be in the proportion of 1 part of cement to 1 part of sand by volume. The materials shall be thoroughly mixed dry, and water then added, while the mixing proceeds, until the grout is of the required consistency. The mixing shall be continued vigorously, preventing the separation of sand, until the entire amount mixed is used.

Concrete will be in the proportion of 1 volume of cement to 3 volumes of sand and 6 volumes of stone, except in special cases where the engineer may require different proportions. For copings and bridge seats to a depth of 9 ins. and in narrow confined places, the smaller sized stone shall be used, and the proportions of sand and stone may be reduced to 2 volumes of the former and 3 volumes of the latter to 1 volume of cement. Whenever practicable the concrete shall be machine-mixed;

the mixing-machine shall be a rotary mixer, and of a pattern that will mix the concrete in batches and permit the definite measurement of the materials for each batch. When the engineer considers it impracticable to mix by machine, it may be mixed by hand, in the same proportions as above specified. The mixing shall be done on a platform of boards or planks securely fastened together. The cement and sand shall first be mixed and made into mortar as described. The broken stone, previously wetted, shall then be added and the mortar and stone turned over with shovels until the mortar is uniformly distributed through the mass and every stone is coated with mortar.

Where the walls of concrete masonry exceed 6 ft. in thickness, masses of stone may be built in; such stone shall be clean, hard, compact, and free from cracks or other unsoundness. They shall be set in at least 6-in. beds of concrete and have full bearings therein. They shall be set on their largest beds and shall be at least 6 ins. apart at every point and at least 12 ins. from the face of the wall. No stone shall be more than 2 ft. in thickness. The large stones shall not in the aggregate exceed 25 per cent of the total volume of the masonry containing them.

The degree of moisture for mortar, grout, and concrete shall be at all times as required by the engineer or his inspector; in general mortar shall be plastic, grout shall be fluid enough to be pumped, and concrete shall be of such consistency that it will quake when being deposited, but not wet enough to cause the stone to separate from the mixture.

Concrete shall be deposited in the work in such a manner as not to cause separation of mortar and stone. It shall be laid quickly in layers not exceeding 9 ins. in thickness and thoroughly rammed with rammers of such form and material as the engineer may approve; special shaped rammers will be required for corners and other places where ordinary rammers would not be effective. Compact, dense concrete must be obtained with all the voids between the stones filled with mortar. If voids are discovered at any time, the defective concrete shall be removed and immediately replaced by concrete of such mixture and in such manner as the engineer may direct.

When the placing of the concrete is suspended, the engineer may require a joint to be formed in a manner satisfactory to

him, so that the fresh concrete, when added, may have a bond. Before depositing fresh concrete the entire surface on which it is to be laid shall be cleaned, washed, brushed, and slushed over with grout of cement without sand.

The surface of freshly laid concrete shall be protected from injury in such a manner and for such time as the engineer may require; concrete injured in any manner shall be removed.

Water used in mortar, grout, and concrete shall be clean fresh water.

No mortar, grout, or concrete which has commenced to set shall be used anywhere in the work. Retempering of mortar or grout which has commenced to set will not be permitted.

Forms for concrete shall be substantial and must preserve their accurate shape until the concrete has set. Where the concrete will show in the finished work, the face of the form shall be built of matched and dressed planking finished truly to the lines and surfaces shown on the plans. Adequate measures shall be taken to prevent the adhesion of mortar to the forms. Forms which have become warped or distorted shall be replaced immediately.

Faces which will show in the finished work shall be true to the form intended and shall be smooth and free from cavities due to shortage of mortar. Exposed faces shall have a facing of mortar, 2 ins. thick, deposited simultaneously with the corresponding layers of concrete and separated from the concrete by a metal diaphragm of approved form. After the mortar and concrete have been deposited the diaphragm shall be removed and the materials well worked together by spading and tamping, so as to insure their bonding. Plastering the face after removing the forms will not be permitted. The facing mortar shall contain 1 volume of cement to 2½ volumes of sand. Copings and bridge seats shall be finished with a layer of mortar 1 in. thick laid on the fresh concrete, thoroughly worked into its surface and finished smooth to true lines and surface by trowelling. They shall be kept damp and protected from the sun and rain for a period of at least 10 days.

Forms shall not be removed until permission has been given by the engineer.

Immediately after the forms are removed the exposed faces of the walls shall be washed over with a neat cement grout applied with a whitewash-brush.

Rock surfaces shall be thoroughly washed and cleaned before

concrete is deposited against them, and no concrete shall be deposited in water.

If leaks appear on the surface of the concrete at any time after removing the form, the contractor shall, at his own cost and expense, remove the concrete through which the water passes and replace it with sound concrete, and shall conduct the water to the base of the wall through channels or pipes in the concrete or take such other measures as the engineer may require.

PROPORTION OF REINFORCED CONCRETE TO THE LOOSE MATERIALS.*

Composition of Mixture in Parts.				Volume of Loose Materials before being Mixed, per Barrel of Cement at 4.25 Cu. Ft.	Volume of Concrete after being Rammed in Place.	Percentage of Rammed Concrete to Loose Materials.
Cement.	Sand.	Broken Stone.	Gravel.			
				Cubic Feet.	Cubic Feet.	
1	2	4	....	29.75	18.75	63.02
1	3	5	....	38.25	23.80	62.22
1	3	6	....	42.50	26.90	63.29
1	4	6	....	46.75	29.25	62.56
1	2	3	3	38.25	24.55	64.18
1	3	....	7	46.75	36.50	78.07

At Fairport and Lorain harbors, Ohio, in work done under the U. S. Engineers, the ratio of the finished concrete to the loose materials were found to be as follows:

At Fairport harbor with concrete of 1 cement, 2 sand, 3 gravel, 4 unscreened broken stone, the ratio in large block work was 69 per cent and in concrete in mass it was 64.6 per cent.

At Lorain harbor with concrete of 1 cement, 2 sand, 3 gravel, 4 screened broken stone, the ratio in block work was 66.9 per cent and in mass concrete was 65.5 per cent.

Quantity of Materials per Cubic Yard of Concrete.—Fuller's formula, which is used by a number of engineers for estimating the quantity of the various materials in concrete, is as follows:

C = number of parts cement;
S = number of parts sand;
g = number of parts gravel or broken stone.

* From Concrete, Plain and Reinforced, by Taylor and Thompson.

Then

$\frac{11}{C+S+g}=P=$ number of barrels Portland cement required for 1 cu. yd. of concrete;

$P \times S \times \frac{3.8}{27}=$ number of yards of sand required for 1 cu. yd. of concrete;

$P \times g \times \frac{3.8}{27}=$ number of cubic yards of stone or gravel required for 1 cu. yd. of concrete.

MATERIALS FOR ONE CUBIC YARD OF CONCRETE.*

Proportion.	Cement, Barrels.	Sand. (Cu. Yds.)	Gravel or Stone, Cu. Yd.
1 : 2 : 4	1.57	0.44	0.88
1 : 2½ : 5	1.29	0.45	0.91
1 : 3 : 6	1.10	0.46	0.93
1 : 4 : 8	0.85	0.48	0.96

If broken stone, screened to uniform size, is used, 5 per cent must be added to all materials. If the coarse material contains a large variety of sizes 5 per cent may be deducted from all of the quantities.

WEIGHT OF CONCRETE AGGREGATES.

Gravel aggregate	weighs	about	80	pounds	per	cubic	foot.
Limestone "	"	"	80	"	"	"	"
Granite "	"	"	90	"	"	"	"
Trap-rock "	"	"	85	"	"	"	"

Wash for Concrete Surfaces.—Slack with warm water, half a bushel of lime, covering it to keep in the steam, and then strain the liquid through a fine sieve; add a peck of salt dissolved in warm water, 3 lbs. of ground rice boiled to a thin paste and stirred in boiling water; ½ lb. of powdered Spanish whiting and a pound of glue which has previously been dissolved over a slow fire, and add 5 gallons of hot water to the mixture. Mix well and let stand for a few days. To use strain carefully and apply hot with a brush or spray. This wash has been used by the U. S. Government in Lighthouse work, and has proven very durable.

*From Concrete, Plain and Reinforced, by Taylor and Thompson.

THE COMPOSITION OF CONCRETE FOR VARIOUS USES.

Nature of Work.	Proportions.				
	Cement	Sand.	Broken Stone.	Lime.	
Sidewalks, base.	1	2	5	. . . . . .	3-in. foundation of broken stone, gravel, or cinders from 6 to 12 ins. deep.
Sidewalks, surface. . .	1	1	. . . .	. . . . . .	1-in. crushed granite or sand.
Concrete, general use.	1	3	7	. . . . . .	Broken stone from ¼ to 2 ins. in diameter.
Portland cement, lime, mortar.	1	7	. . . .	1	
Concrete bridge foundations and abutment walls.	1	3	6	. . . . . .	Stone to pass ring 1½ ins. in diameter.
Concrete haunches, arches, catch-basins	1	2	5	. . . . . .	Stone to pass ring 1½ ins. in diameter.
Plastering faces of concrete arch and catch-basins.	1	1½	. . . .	. . . . . .	
Stable floors, base. . .	1	1½	3	. . . . . .	3 ins. thick.
Stable floors, surface.	1	1	. . . .	. . . . . .	2 ins. thick, hard-trowelled. Very fine sand, or preferably crushed granite.
Repairing masonry. . .	1	3	. . . .	. . . . . .	
Stucco.	1	3	. . . .	¼	½ to ¾ in. thick.
Plastering brick wall, first coat containing hair.	1	. . . . . .	. . . .	¼	½ in. thick.
Plastering brick wall, second coat applied before the first has set.	1	2	. . . .	. . . . . .	¼ in. thick.
Concrete tanks, cisterns, etc.	1	2	5	. . . . . .	Stone to pass 1-in. ring.
Concrete pillars, posts, walls, etc.	1	2	3	. . . . . .	Broken stone to ¾-in. ring.
Ornamental work. . . .	1	2	3	. . . . . .	Fine-crushed granite.
Cinder and cement concrete for fireproof floors.	1	2½	6 parts steam cinders	. . . . . .	
Cement grout for pouring between concrete blocks. . . .	1	1	. . . .	. . . . . .	Water should be added in sufficient quantity to produce a fluid condition.

Concrete Wash.—The facing of concrete work employed by the Wabash Ry. for bridge abutments of concrete and concrete-steel consists in applying a facing wash composed of 1 part of plaster of Paris to 3 parts of cement, made very thin

and put on with whitewash-brushes. This has been found very satisfactory.

LIME CONCRETE.—In Paris a concrete is much used, composed as follows:

Sand and gravel 8 parts, burned and powdered earth 1 part, pulverized clinkers and cinders 1 part, and unslaked hydraulic lime $1\frac{1}{2}$ parts. These materials are thoroughly mixed while dry and then dampened. This mixture sets in a short while and becomes very hard and strong in a few days. It is claimed for this concrete that it is not liable to crack or scale.

Experiments for volume on cement, sand, gravel, broken stone, mortar, and concrete are shown in the following table, the volumes being measured loose:

Cement.	Volume of Loose Cement.	Water Added by Measure.	Volume of Stiff Cement Paste.
Portland cement (Atlas).......	1.00	0.35	0.78
Natural cement. Louisville.....	1.00	0.43	0.78

Remarks.—6.56 barrels of cement = 1 cubic yard measured loose.

Aggregates.	Volume Loose.	Solids.	Voids.
1. Sand, moist, fine, will pass 18-mesh sieve..	1.00	0.57	0.43
2. Sand, moist, coarse, will not pass 18-mesh sieve............................	1.00	0.65	0.35
3. Sand, moist, coarse and fine mixed (ordinary)...........................	1.00	0.62	0.38
4. Sand, dry, coarse and fine mixed........	1.00	0.70	0.30
5. Stone screenings and stone dust..........	1.00	0.58	0.42
6. Gravel, $\frac{3}{4}$ in. and under, 6 per cent coarse sand............................	1.00	0.67	0.33
7. Broken stone, 1 in. and under...........	1.00	0.54	0.46
8. Broken stone, $2\frac{1}{2}$ ins. and under, dust only screened out.........................	1.00	0.59	0.41
9. Broken stone, $2\frac{1}{2}$ ins. and under, most small stones screened out...................	1.00	0.55	0.45

MORTARS WITH NO. 3 SAND.

Parts of sand mixed with 1 part of cement........................	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
Volume of slush mortar..........	1.40	1.78	2.17	2.55	2.98	3.39	3.82	4.65
Required for 1 cubic yard:								
Cement, bbls................	4.70	3.70	3.04	2.58	2.21	1.94	1.72	1.41
Sand, cubic yards...........	0.71	0.84	0.92	0.98	1.01	1.03	1.05	1.08
Volume of dry facing mortar (rammed)...................	1.22	1.57	1.93	2.28	2.64	2.99	3.35	4.08
Required for 1 cubic yard:								
Cement, bbls................	5.40	4.18	3.41	2.88	2.49	2.20	1.96	1.61
Sand, cubic yards...........	0.82	0.95	1.04	1.10	1.14	1.17	1.20	1.23

MATERIALS REQUIRED TO MAKE DIFFERENT CLASSES OF CONCRETE FOR CONNECTICUT AVE. BRIDGE, WASHINGTON, D. C.

The following concrete preparations were determined by Mr. A. W. Dow, Inspector of Asphalts and Cements, and W. J. Douglas, Engineer of Bridges, D. C.

Class A.

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.
9.00 cu. ft. sand.
20.25 " " stone.
Yielded 21.4 cu. ft. concrete when rammed into place.

Class B.

1:2½:6 (broken stone).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.
11.25 cu. ft. sand.
27.00 " " stone.
Yielded 27.66 cu. ft. concrete when rammed into place.

Class B.

1:2½:3:3 (3 gravel and 3 stone).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.
11.25 cu. ft. sand.
13.50 " " gravel.
13.50 " " stone.
Yielded 27.66 cu. ft. concrete when rammed into place.

Class C.

1:3:10 (gravel).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.
13.5 cu. ft. sand.
45.0 " " gravel.
Yielded 45 cu. ft. of concrete when rammed into place.

NOTES ON CEMENT CONCRETE, ETC.—Good cement should be a uniform bluish-gray color throughout; yellow checks or places indicate an excess of clay or that the cement has not been sufficiently burned; and it is then probably a quick-setting cement of low specific gravity and deficient strength.

Cement that will stand a high test for seven days may have an excess of lime, which will cause it to deteriorate. The twenty-eight-day test is, therefore, very useful.

The most dangerous feature in Portland cement is the presence of too much magnesia and an excess of free lime, the latter indicated by the cracks and distortions in the test cakes and the former in the deficiency of tensile strength of the briquettes. Over 3 per cent of magnesia is excessive and dangerous.

For general information the following building material will make 1 cubic yard of concrete: 2400 pounds crushed stone, 295 pounds cement, 880 pounds sand, 700 pounds rough building stone.

Cement work which is to be painted must be fully hardened and dry. The best results are obtained after the concrete is a year old. A good preparatory coating for oil paint is a solution of water-glass (silicate of soda and potash dissolved in water) in 4 parts of water. After two applications the surface is washed with water and water-glass applied again. When thoroughly dry the paint can be used.

The quality of cement-work is always improved by keeping it wet, especially during the process of setting. Cement should in no case be disturbed after it has attained its initial set.

When metal moulds are used for forming concrete, or metal lining for wooden forms, ordinary pork fat has been successfully used to prevent adhesion.

PER CENT OF STRENGTH OF CONCRETE AT DIFFERENT AGES.

30 days old,	60 per cent of full strength.
60 " "	75 " " " " "
90 " "	85 " " " " "
120 " "	90 " " " " "
180 " "	95 " " " " "
360 " "	100 " " " " "

NUMBER AND MESH OF SIEVES FOR TESTING CEMENT.

No. 50.............	2,500 meshes to the square inch
No. 74.............	5,476 " " " " "
No. 100.............	10,000 " " " " "
No. 200.............	40,000 " " " " "

The porosity of mortar and cement, according to recent tests made by Prof. Lang, shows that when wet Portland cement

concrete is impermeable to air. By measuring the amount of air which passes a layer of given thickness, under a certain pressure, in a unit of time, the following values for the degree of permeability were obtained:

	Dry.	Wet.
Portland cement, neat..................	0.05	0.00
Portland-cement concrete...............	0.40	0.00

The specific gravity of Portland cement is between 3.10 and 3.25.

The specific gravity of cement is the figure which denotes the density of a sample or the number of times a given volume of it is weightier than the same volume of water.

For cement pipe use the following proportions: one part cement to three parts of sand and gravel. After the pipe is removed from the mould it should be coated with a wash of neat cement and water, of the consistency of paint, applied with a brush, to prevent seepage of water when in service.

Neat cement reaches a greater strength at short periods than sand mixtures. Concrete, however, gains in strength gradually, and ultimately surpasses neat cement in strength.

The compressive strength of cement is usually from eight to twelve times the tensile strength.

Quick-setting cement requires more water than slow-setting cement.

Temperature of water and atmospheric conditions naturally affect setting time.

Saline water retards setting.

A sand mixture of a cement which does not stand the neat pat test perfectly may show no imperfections whatever. Sand tends to diminish the ill effects of some inferior qualities.

Finely ground cement has greater capacity for sand, ages more rapidly, sets quicker, gets ultimate strength quicker, requires more water, is lighter in color, shows lower tensile strength in neat briquettes, shows greater tensile strength in sand briquettes, than the same cement not so finely ground. The finer the grinding, the more active the cement.

Aged cement as a rule sets slower. shows lower tensile strength in early breaks (one, three, and seven days especially), shows greater tensile strength in later breaks, is more liable to withstand pat tests, has smaller capacity for sand, than the same cement when tested fresh.

Cement is packed in barrels, cloth sacks, or paper bags, as ordered. A barrel of Portland cement contains 380 lbs. net of cement, and weighs about 400 lbs. A barrel of eastern natural hydraulic cement weighs about 320 lbs gross, and should contain 300 lbs. net of cement. A barrel of western natural hydraulic cement weighs about 285 lbs. gross, and should contain 265 lbs. net of cement. Slag cement weighs 330 lbs. to the barrel. Cloth sacks contain one-fourth of a barrel of Portland cement, and ordinarily one-third of a barrel of natural hydraulic cement. A carload of Portland cement usually means 100 barrels (40,000 lbs.); 75 barrels in the minimum carload, or the same quantity by weight in cloth or paper bags.

When cement is ordered in cloth sacks, the sacks are charged at cost, viz.: 10 cents each in addition to the cost of cement; but when the sacks are returned to the works in good condition, freight prepaid, 10 cents is allowed for each, with a deduction of 2 cents for wear and tear in some cases. For paper bags there is no charge, as they are not to be returned. Empty sacks to be returned should be safely tied in bundles of 10 or 50, giving the name of the sender.

Sand weighs from 80 to 100 pounds per cubic foot loose, and about 20 lbs. more when well rammed. Crushed limestone weighs about 90 lbs. per cubic foot, varying somewhat either way with the size and amount of fine dust. Concrete weighs about 140 lbs. per cubic foot. Lime paste about 50 per cent water, 1 cubic foot of quicklime and 1 cubic foot of water make $1\frac{1}{8}$ to $1\frac{1}{4}$ cubic feet of stiff lime paste.

Portland cement loose weighs 70 to 90 lbs. per cubic foot; packed, about 110 lbs. per cubic foot. One barrel is $3\frac{1}{2}$ cubic feet, weighing 380 lbs. net or 400 lbs. gross. Foreign cement barrels contain $3\frac{1}{3}$ or less cubic feet.

Natural hydraulic cement, loose, weighs 50 to 57 lbs. per cubic foot; packed, about 80 lbs. per cubic foot. One barrel, 265 lbs., western cement; 300 lbs., eastern cement. Weights of cement and volumes of barrels are not uniform. Nearly all natural hydraulic cement is sold in casks, as given above.

In moulding a concrete block the operation should always be continuous and great care exercised in compacting the cement next to all parts of mould which form the exterior surfaces. Great care should be exercised in removing the moulds, which under ordinary circumstances can be done twenty-four hours

after the concrete has been in place. The block, after removal of the mould, should be shaded by canvas or heavy burlap and kept thoroughly wetted for a number of days.

Neat cement reaches a greater strength at short periods than sand mixtures. Long-time tests prove, however, that sand mixtures ultimately attain equal and often greater strength than neat cement.

The compressive strength of cement is from eight to twelve times the tensile strength.

The shearing strength of concrete can be roughly estimated at from 60 to 75 per cent of the compressive strength.

White sand or marble dust used in making concrete gives the finished work a lighter color than is attained by using ordinary sand.

When salt is used in concrete to prevent freezing, it should always be thoroughly dissolved in water before it is added to the cement—8 to 10 per cent of the weight of water used is the proportion of salt to use.

Cement mortar or concrete is said to have set when it becomes non-plastic and its shape cannot be changed without causing a crack or fracture.

Hot water hastens setting time.

Too much water retards setting time.

Finely-ground cement has greater capacity for sand.
" " " ages more rapidly.
" " " gets ultimate strength quicker.
" " " requires more water.

From an engineering standpoint, limes and cements have been classified by Taylor and Thompson, in "Concrete, Plain and Reinforced," as follows:

Portland Cement;
Natural Cement;
Puzzolan Cement;
Hydraulic Lime;
Common Lime.

PART III.

MORTAR AND MATERIALS FOR MAKING, REINFORCED CONCRETE, CONCRETE PILES, FORMS AND CENTERING, LAYING OUT WORK, SHORT CUTS, AND METHODS OF DOING WORK.

Mortar and Materials for Making.—Mortar, like concrete (in fact, mortar is a fine concrete), depends for its quality and strength upon the materials of which it is made, and on the proportions in which the materials are used.

The use and purpose of mortar usually is to give a bed and cause adhesion between the stones or bricks of a wall, and also to fill the voids or cavities between the stones or bricks.

The nature of the mortar to be used will depend on the nature of the wall or of the materials of which the wall is to be built.

"Press" brick or cut stone work will require a fine mortar, while a rubble stone wall or a wall of largé blocks of stone will require a much coarser mortar; likewise ordinary brickwork requires a coarse mortar. The fineness or coarseness of a mortar is governed by the size of the grains of sand used, and these grains, no matter what their size may be, should be angular and sharp to make good mortar. When making mortar it should be remembered that

Poor materials make poor mortar.
Too large a proportion of sand makes poor mortar.
Too little mixing makes poor mortar.
Good materials, mixed in correct proportions and mixed thoroughly, make good mortar.

Lime Mortar.—Lime mortar is made by slaking the lime and adding sand in the desired proportion. The slaking is usually done by putting the lime in a water-tight box and covering with water. The lime is then stirred with the hoe so as to let the water get to all sides of the lumps of lime and thus cause it to slake more readily. Enough water is added to make the mixture about the consistency of thick cream. It is then run off through a sieve into a larger box, where the sand is added and the mortar allowed to cool a little and thicken. The amount of sand used is regulated by the quality of the lime used, as some limes will take more sand than others.

The "mortar-man" when slaking lime can usually tell when he has enough sand added as he "runs it off," but if it is a little "rich," as it usually is, he will add more sand when he tempers it up for use. The mortar should have just enough sand in it to make it work nicely and not stick to the trowel.

The "mortar-man," by a little experience with and watching the mortar, will be able to tell at a glance if the mortar is "rich" or "poor." Mortar should be run off at least three days before using, so that the lime will have time to cool off and there will be no small particles of lime left unslaked and which may slake after being built in the wall.

Lime mortar should not be used in freezing weather, although if it is frozen hard and dry without any thawing it hardly ever affects it much, but if it is alternately frozen and thawed the mortar will lose its strength and be destroyed; so, to be on the safe side, it is well to follow the rule of using no lime mortar in freezing weather.

Ground lime is now used in nearly all parts of the country, as this lime can be mixed and used immediately.

In making mortar for laying "press" brick or brick with a close joint, a fine white sand or marble-dust is generally used.

The New York Building Code requires that lime mortar be made of 1 part of lime and not more than 4 parts of sand.

Sugar in Mortar.—Sugar has been used for centuries in India in the making of lime mortar and is said to add greatly to its strength. Experiments were made some years ago to ascertain the effect of sugar on Portland cement, and an addition of from $\frac{1}{8}$ to 2 per cent of pure sugar added to Dyckerhoff German Portland cement was found to considerably increase its strength after three months. The sugar was said to "retard

its setting," and thus permit the chemical changes in the cement to take place more perfectly, but more than 2 per cent of it rendered the cement useless. As sugar is soluble in water it should never be used in mortar which is to be used under water.

PORTLAND-CEMENT–LIME MORTAR.[1]—"There are many kinds of work which require a quick-hardening mortar, but for which the great strength of a mixture of 1 of cement with 1 to 4 of sand is unnecessary. The cost of such mortar is also for many purposes too high. A mixture of cement with 5 or more parts of sand would give abundant strength, but such mortar works too 'short' and adheres too imperfectly to the stone or brick; it cannot therefore be safely used. In such cases the addition of slaked lime or hydraulic lime will correct the faults of poor mixtures of cement and sand, and will produce a cheap mortar suitable for a great variety of uses. Used in this manner, Portland cement may be used with economy for the most ordinary purposes. The advantages of Portland-cement–lime mortar are its cheapness in comparison with other hydraulic materials, its rapid hardening, marked hydraulic properties great strength on exposure to air, and remarkable resistance to weather.

"The following mixtures for cement-lime mortar have been found by experience to be most suitable:

"Cement,	1 part;	sand,	5 parts;	lime	paste,	½ part	
"	1 "	"	6 to 7 parts;	"	"	1	"
"	1 "	"	8 parts;	"	"	1½ parts	
"	1 "	"	10 "	"	"	2	"

"The above proportions are to be taken by measure. Hydraulic lime may be used in the place of ordinary slaked lime.

"Cement-lime mortar is prepared by making a dry mixture of the required quantities of cement and sand; milk of lime is then made with the necessary quantities of lime paste and water and this milk of lime thoroughly mixed and worked in with the mixture of sand and cement."

In laying face brick in cement mortar it is advisable to add a little lime "putty" to the mortar, as it makes the mortar work smooth and the mason can do a neater job. Mixtures of cement with three parts or more of sand are found to work

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[1] Extracts from "Das Kleine Cement-Buch."

too "short" for rapid and easy work in laying brick or stone. The addition of lime paste removes this defect and makes the mortar smooth and plastic. The adhesion of the mortar to brick or stone, and also its impermeability to water, are greatly increased by the addition of slaked lime. As to strength, it will be found that a mixure of Portland cement 1, lime paste 1, sand 6, is as good in every respect as a mixture of Portland cement 1, sand 3; or, in other words, that one-half the cement may be replaced by lime paste without loss of strength.

Compared with mortar made with Louisville, the Portland-cement–lime mortar will be found immensely stronger and little or no more expensive.

Cement Mortar.—In making cement mortar the strength of it depends on the quality of the cement and sand, the proportions used, and the manner of mixing. The sand should be sharp and irregular, as described on page 79, the finest depending on the nature of the work in which the mortar is to be used.

For mortar for laying brick or for grouting, it should be comparatively fine, while for concrete or coarse mortar it should range from fine to coarse. A small amount of pure clay in the sand used for cement mortar will not affect its strength.

Proportions.—The proportions of cement and sand for cement mortar varies according to the cement used and the strength of the mortar desired.

The most common mixture is 1 to 3 for Portland cement and 1 to 2 for natural cements. There must be enough cement to more than fill all the voids in the sand and make a compact mass.

For masonry and brickwork use 1 part cement to 2, 3, or 4 parts of sand, according to the strength required and the purposes for which the mortar is to be used; for some special purposes 5, or even 6, parts of sand may be used.

Cement mortar for face brickwork is usually composed of 1 part cement and 2 parts sand; for backing and in ordinary masonry foundations it is not necessary to use a richer mortar than 1 part cement to 3 of sand. When large quantities of sand are used the mortar is "short" and brittle and will not work well.

In some cases lime paste is added to the cement mortar to

give it the required plasticity. The proportions are about one-half part lime paste added to the mortar.

Stone-dust and fine screenings have been used as a substitute for sand and gave as strong a mortar as if sand had been used. The tables on pages 54 and 85 show the average strength of cement mortars of different proportions and age.

WATER-TIGHT MORTAR.—For the lining of cisterns and reservoirs, and also in some cases for the protection of underground conduits and piping, a mortar which is impermeable to water is required. According to Dykerhoff the following mixtures will be found water-tight as soon as set:

Portland cement, 1;	sand, 1;		
" " 1;	" 2;	lime paste,	½
" " 1;	" 3;	" "	1
" " 1;	" 5;	" "	1½

From the above mixtures the one may be chosen which offers the required strength and hardness.

A solution of 1 pound of concentrated lye, 5 pounds of alum, and 2 gallons of water mixed with cement in the proportion of 1 pint of the solution to 5 pounds of cement and applied with a brush and well rubbed in will make cement walls waterproof.

TO COLOR CEMENT MORTAR.—*Black.*—Use 45 pounds of manganese dioxide to a barrel of cement.

Brown.—Use 25 pounds of best roasted iron dioxide to a barrel of cement, or 15 or 20 pounds of brown ochre.

Blue.—Use 19 pounds of ultramarine to a barrel of cement.

Buff.—Use 15 pounds of ochre to a barrel of cement, but this will greatly reduce the strength of the mortar.

Green.—Use 23 pounds of greenish-blue ultramarine to a barrel of cement.

Gray.—Use 2 pounds of Germantown lampblack (bone-black) to a barrel of cement.

Red.—Use 22 pounds of raw iron oxide to a barrel of cement.

Red-bright.—Use 22 pounds of Pompeiian or English red to a barrel of cement.

Purple.—Use 20 pounds of prince's metallic paint powder to a barrel of cement.

Violet.—Use 22 pounds of violet oxide of iron to a barrel of cement.

Yellow.—Use 22 pounds of ochre to a barrel of cement.

Ultramarine is one of the best coloring materials, as it does not affect the strength of the mortar. Germantown lampblack is also good on account of the small quantity necessary to give a good color.

Do not use common lampblack or Venetian red, as they are liable to run and fade.

In coloring mortar the coloring should be mixed in the sand and cement dry, and the wet mixture should be made several shades darker than required, as the wet mortar looks darker and brighter to the eye, owing to the gloss of the water, than it really is

Mortar is one of the principal materials used in construction, and upon which the strength and stability of the structure depends to a great extent; hence the different materials and proportions used in making the mortar should be the best of their several kinds.

SAND.—Sand, which enters largely into the composition of all mortars, should be sharp and angular and comparatively free from any dirt or loam. Recent experiments have shown that a slight percentage of clay in the sand used for cement mortar does not affect its strength, but there should not be more than 5 per cent of clay in the sand. For rough stonework or common brickwork the sand should be coarse, but for "press" brick and setting ashlar it should be fine, so as to get a close joint.

The sand for mortar for either stonework or brickwork should be clean, coarse, and sharp. A good quartz sand is the best.

A very fine sand does not make as good mortar as the coarse, and very fine sand should not be used unless for brickwork where a close joint is desired; but when the sand is used in large proportions to the lime or cement, a sand ranging from fine to coarse will make the best mortar. A loamy or dirty sand should not be used, as it will weaken the mortar.

Marble-dust is often used in place of sand where a close joint is desired in the work.

By taking a small amount of sand and spreading it over the hand or examining it with a magnifying-glass a person can readily ascertain its quality.

QUICKSAND.—Sand which has been worn round and very fine

by the action of water is known as quicksand and should never be used in making mortar or concrete. This sand is easily distinguished, as the particles are round and very small, some of it being almost a powder. In the pile it is continually running down, thus making a very flat pile.

Good sharp sand can be cut down in the pile with a perpendicular face, but this cannot be done with quicksand, as it slides like so many round balls.

When used in mortar quicksand will settle to the bottom and the mortar has to be continually mixed or tempered. Sand of this kind will make a very weak mortar or concrete.

Lime.—Lime is obtained by burning limestone. When carbonate of lime is calcined the carbonic acid is thrown off and lime is obtained. It is then known as caustic lime or quicklime; if it then be mixed with water it will throw out great heat, swell to several times its original bulk, and finally falls to a powder. In this state it is known as slaked or a hydrate of lime.

The quality of lime depends on the composition of the limestone from which it is made. Those stones which are nearly pure carbonate of lime make the best lime, while those which contain large amounts of impurities, such as silica, clay, magnesia, and alkalies, make the poorest lime according to the amount of impurities contained.

Good lime should be free from cinders or unburned stone and not contain a large per cent of impurities; over 10 per cent of impurities makes poor lime and it should be rejected.

Lime should be in large hard pieces and contain little dust. When wet with water it should slake readily into a smooth, fine paste or putty. The lime should slake by simply immersing it in the water, although stirring it will hasten it somewhat.

Hydraulic Lime.—Hydraulic lime is made from calcareous rock containing 12 to 30 per cent of silica, alumina, iron, and magnesia; when calcined at a low temperature it will slake and will set and harden in water in from one to ten days to five or six months, depending on the amount of silica and alumina contained. Hydraulic lime is not used much in this country, as natural cement takes its place. The following is an average of French hydraulic lime:

Silica	22.0 per cent
Alumina	2.0 " "
Oxide of iron	1.0 " "
Lime	63.0 " "
Magnesia	1.5 " "
Sulphuric acid	0.5 " "
Water	10.0 " "
	100.0 per cent

Mortar Made with Caked Cement.—Cement which has drawn dampness enough to cause it to cake in the bag can be used, providing the cakes can be broken and pulverized on the mixing platform with a shovel. Any lumps which cannot be easily crushed should be thrown out or considered as a part of the aggregate and enough good cement added to take the place of these lumps.

The strength of mortar made with caked cement may be as great as the strength of mortar made with cement in good condition. A table showing the results of tests on Portland cement mortars is given on page 380, Vol. 8, Part IV, Report of the Chief Engineers, U. S. A., 1894, from which the following has been abstracted:

Character of Cement.	Age of Mortar when Broken.	Tensile Strength. Lbs. per Sq. In.	Number of Tests Averaged.
Good	7 days	176	8
Caked	7 "	199	2
Good	28 "	298	8
Caked	28 "	274	5
Good	6 mos.	424	8
Caked	6 "	424	5

The cement that was caked had been exposed to dampness in sacks until caked hard, but not set. It was then pulverized and treated exactly as the good cement was treated, being mixed with 3 parts of standard quartz sand, by weight, to 1 part of cement.

Taylor and Thompson in "Concrete Plain and Reinforced" states:

1. "The tensile or compressive strength of Portland cement mortars or concretes is not lowered by standing two hours after mixing.

2. "Continuous gaging increases the ultimate strength.

3. "Regaging makes the cement slower setting

"With natural cements, however, the results of experiments are somewhat contradictory. It is probable that some natural cements are injured, and therefore if circumstances require delay in placing natural cement mortar, the effect of such delay should be determined by tests upon the brand to be used."

Relative Strength of Cement Mortar.—The following table gives the result of an experiment made at the Holyoke Dam, Mass., showing the tensile strength of various mixes and their ratio to standard neat cement mortar. The briquettes being kept in water (after twenty-four hours) until broken, which at twenty-eight days develops 889 pounds:

Proportion of Sand to Cement.	Pounds.	Ratio.
1 : 1	805	90
2 : 1	589	68
3 : 1	343	39
4 : 1	204	23
5 : 1	133	15
6 : 1	121	14
7 : 1	71	8
8 : 1	53	6
9 : 1	44	5

Remixed Cement Mortar.—Recent experiments by various engineers have shown that remixed Portland cement mortar, or mortar that has acquired its initial set and is then remixed thoroughly, is as strong after a long period of time as if it had not been disturbed after its first set. However, unless for special reasons, it is always best to use all mortar before it has commenced to set.

Remixed mortar is much slower setting than the original mixture, but is weaker in strength up to about six months, after that the strength is about the same.

The strength of remixed mortar depends on the second mixing, which must be thorough, until the mortar is a uniform plastic mass.

Natural or Rosendale cement will not stand remixing as well as the Portland cements.

Mixing Mortar.—In mixing lime mortar the strength of the mortar or amount of sand to be used is usually left to the judgment of the "mortar-man," for by experience he can tell by the working of the mortar when he has given what sand the lime will carry. No definite rule can be given for

measuring sand in lime mortar, for some limes will take more sand than others.

In mixing cement mortar the wheelbarrow is often used as the unit of measure, but at times it is difficult to get the workmen to measure correctly by this method, and the author presents the following method, which he uses:

Obtain the depth of the mixing-box and make a straight-edge, as shown by *A*, Fig. 3, so as to strike off the sand and cement at the proper levels to measure it correctly.

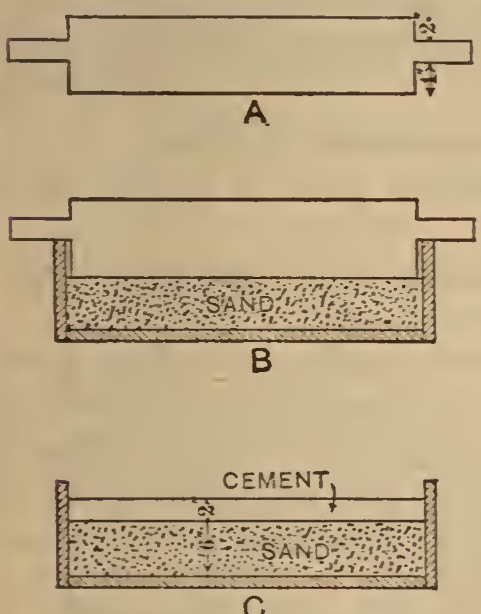


FIG. 3.—Measuring Mortar Materials.

In the example shown by Fig. 3 the box is 10 inches deep and the mortar to be mixed 1 to 3. We will notch one side of the straight-edge 4 inches, which will strike off the sand in the box 6 inches deep. On the opposite side of the straight-edge we will make the notch 2 inches deep, which will strike off the cement 2 inches deep on top of the sand, thus giving a layer of sand 6 inches deep with a layer of cement on top 2 inches deep.

This method can be used for a full box of mortar or any part of a box. The author has derived much satisfaction by using this method, as it insures the sand and cement being measured correctly, and it also spreads the cement over the sand uniformly, so that the mixing is much easier and more uniformly than when the cement is thrown on top of the sand without spreading it in a uniform layer.

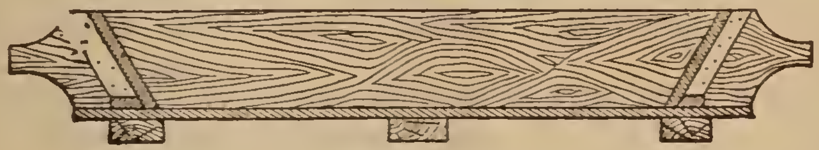


FIG. 4.—Mortar-box.

MORTAR-BOX.—Fig. 4 shows how a mortar-box should be built. The handles at each corner, as shown, enables four men to carry it very easily. The ends should always be set

on a slant, as shown, so the blade of the hoe can be got down into the angles and the box scraped clean. At the close of the day's work the box should be scraped and washed clean.

RULES REGARDING USE OF MORTAR.—Lump lime-mortar should be made up three or four days before required for use and then tempered as desired.

Ground lime can be used the same day it is made into mortar, but it is better to let it stand a day before using.

Do not use mortar that is too soft or sloppy, as neat joints cannot be made.

Do not use mortar of any kind in freezing weather.

Have cement-mortar mixed so that none of it will stand over two hours before being used.

When mixing cement-mortar mix the sand and cement dry to a uniform color before adding the water.

Grouting.—Grout is a thin mortar usually made of sand and cement, and is generally used in brickwork, by building up the two outside courses of the wall, then laying the inside bricks and pouring the thin mortar over them, working it well into all the joints. The grouting should be done every course, so that all the joints will be filled solid.

Grouting is done when extreme strength and solidity are desired.

MORTAR FOR POINTING.—The mortar for pointing should be mixed with cement and fine sand or marble dust, so that the mortar will dress off smooth under the jointing tool.

The mortar should be used very stiff and should be rammed or packed solid into the joint.

In case the mortar works "brittle" and will not smooth off easily, add a little lime putty, not over 10 per cent.

WHAT ONE BARREL OF LIME WILL DO.

1 barrel of lime will make $2\frac{3}{4}$ barrels of paste.
1 " " " " lay 3 perch of stone rubble.
1 " " " " " 1000 to 1200 bricks.
1 " " " " plaster 28 yards of 3-coat work.
1 " " " " " 40 " " 2- " "
1 " " " " equals 3 bushels of 80 pounds each.

The following tests of the tensile strength of Portland-cement mortar of different proportions and age were made by the New York State Canal Commission. The cement used was Glens Falls "Iron Clad."

NEW YORK STATE CANALS.
DEPARTMENT OF CEMENT TESTS.

Record of cement tests made with the Glens Falls "Iron Clad" Portland cement, showing tensile strength in pounds per square inch. All briquettes kept in air twenty-four hours, balance of time in water. Figures below represent in each case the average of five briquettes. Quartz was used in mixing all briquettes.

Kept in Water.	Amount of Water Used.					
	2½ oz.	1¾ oz.	1½ oz.	1½ oz.	1¼ oz.	1 oz.
	Proportions Used in Mixing.					
Number of Days.	Neat.	1 Sand, 1 Cement.	2 Sand, 1 Cement.	3 Sand, 1 Cement.	4 Sand, 1 Cement.	5 Sand, 1 Cement.
7	515	546	327	210	162	133
14	620	568	342	232	156	150
18	651	651	420	247	222	149
28	671	660	425	277	227	169
30	715	665	446	265	233	171
Number of Months.						
3	776	714	542	347	225	184
6	784	811	540	441	217	159
9	744	712	490	375	259	202
12	784	714	535	380	257	194
15	836	720	536	395	292	204
18	848	771	573	396	271	216
21	920	750	555	411	298	238

(Signed) HERSCHEL ROBERTS.
Deputy State Engineer and Surveyor.

The following tests as to the tensile strength of natural-cement mortar were made with the "Improved Shield" brand of Rosendale cement:

		Neat Cement.	1 Cement, 2 Sand.
Tensile strength in	24 hours	115 lbs.	......
" " "	3 days	161 "	......
" " "	7 "	234 "	142 lbs.
" " "	30 "	318 "	278 "
" " "	60 "	374 "	352 "
" " "	90 "	398 "	418 "
" " "	180 "	440 "	500 "
" " "	360 "	501 "	568 "

LONG-TIME TESTS.

Tests of nearly Five Hundred Thousand Barrels "Giant" Portland, on six of the largest dams in the United States: on the Niagara Falls Power Tunnel; on the Boston Aqueduct; the Washington, D.C., Sewers; and the Reading Terminal Railroad and Station, in Philadelphia, for periods up to nine years.

Brand "Giant" Portland.	Mode of Mixing.	1 Day.		1 Week.		1 Mo.		3 Mos.		6 Mos.		9 Mos.		1 Year.		15 Mos.		18 Mos.		Fineness.
		Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Residue on No. 100 Sieve.
* Sodom and Bog Brook Dams, New York Aqueduct....	Neat	1025	140	1398	348	220	422	180	540	100	634	30	638	180	682	30	687	110	672	18.0
	2 to 1	....	....	220	166	120	280	140	364	84	468	50	468	90	490	36	526	100	530	
	3 to 1	....	....	226	140	140	234	112	350	110	428	30	428	240	420	40	500	80	514	
Titicus Dam, New York Aqueduct.....	Neat	3448	157	4165	380	637	476	505	529	478	575	479	599	350	642	181	594	135	584	11.7
	2 to 1	....	....	2934	200	424	317	281	450	321	491	278	532	219	549	157	557	92	541	
	3 to 1	....	....	1604	115	260	185	450	289	133	347	146	311	132	426	70	424	66	416	
				2 Years.		3 Years.		4 Years.		5 Years.		6 Years.		7 Years.		8 Years.		9 Years.		
* Sodom and Bog Brook Dams, New York Aqueduct....	Neat	....	....	110	694	90	736	60	771	*4	646	*6	583	*2	585	2	749	2	817	18.0
	2 to 1	....	....	100	564	130	680	120	674											
	3 to 1	....	....	80	512	160	572	....	....	*4	486	*5	491	*1	618					
Titicus Dam, New York Aqueduct....	Neat	....	....	137	641	62	668	54	699	64	704	6	647		....	....	....	....	....	11.7
	2 to 1	....	....	52	536	37	573	13	565	38	610	5	631							
	3 to 1	....	....	126	419	7	483	56	539	42	540	5	611							

* Up to 4 years briquettes at Sodom were broken in the laboratory on the dam. Subsequently they were broken at Cornell Dam, after having been out of water for some months, between October, 1893, and June, 1894, which explains the temporary falling off.

LONG-TIME TESTS—*Continued.*

Brand "Giant" Portland.	Mode of Mixing.	1 Day.		1 Week.		1 Mo.		3 Mos.		6 Mos.		9 Mos.		1 Year.		15 Mos.		18 Mos.		2 Years.		3 Yr's.		Fineness.
		Number of Briquettes.	Average in, Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	No. of Briqu'ts.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	Number of Briquettes.	Average, in Pounds.	No. of Briqut's.	Average, in Pounds.	Residue on No. 100 Sieve.
Carmel and Craft's Dams, New York Aqueduct.	Neat	1786	140	1075	343	324	443	551	517	529	548	491	568	289	617	..	...	273	604	211	611	..	...	14.7
	2 to 1	....	...	1642	182	216	308	85	445	87	480	76	472	43	585	..	...	49	477	55	475	3	538	
	2 to 1 from mortar box	....	...	61	164	51	237	8	385	11	494	8	491	7	367	..	...	12	516	3	568			
	3 to 1	....	...	13	100	13	174	7	319	12	372	11	398	10	413	..	...	8	401	10	406			
	3 to 1 from mortar box	....	...	45	112	31	166	6	310	8	480	7	500	9	541	..	...	7	437	5	406			
Reading Terminal Railroad and Station, Phila.	Neat	....	...	329	315	267	376	69	451	15	549	16	576	10	523	1	640	...	...	...	...	...	...	14.79
	3 to 1	....	...	536	79	431	129	104	174	20	228	15	225	47	261	5	287							
	2 to 1 from mortar box	....	...	190	84	180	144	17	219	13	234	25	281	62	325	12	417							
Niagara Falls Tunnel, Niagara Power Co.	Neat	....	...	495	321	309	420	12	514	24	562	...	...	24	661	..	...	...	...	...	...	...	...	14.9
	2 to 1	....	...	482	152	271	242	54	369	20	454	...	...	7	472									
	3 to 1	....	...	527	98	399	177	143	254	181	301	...	...	12	391									
Cornell Dam, New Croton Aqueduct. Largest masonry dam in the world.	Neat	2677	186	2699	413	405	525	190	559	110	600	120	601	105	679	55	713	53	679	36	722			
	2 to 1	....	...	2624	303	415	432	180	558	110	664	110	663	90	707	43	700	53	701					
	3 to 1	....	...	....	...	...	...	...	...	...	...	...	...	10	482	10	529	5	534					
Dist. of Columbia. Giant (Egypt)	Neat	....	188	....	278																			
	3 to 1	....	...	....	159	...	205	...	240	...	341	...	360	...	394	..	...	...	...	...	417			
Metropolitan Water Board of Boston, Mass.	Neat	1510	293	617	453	40	486	20	540	5	567	...	...	...	...	..	...	...	...	...	...	...	...	8.6
	2 to 1	....	..	616	282	40	339	20	438	5	549													

Reinforced Concrete.—This work not being intended as a text-book for engineers, but as a help to the ordinary mechanic or worker in concrete, no intricate formulas or complicated diagrams regarding strength of reinforced concrete will be given, but the following on reinforced concrete, and which is used by permission of the Atlas Cement Co., should be of great value to any mechanic or worker in concrete construction.

"Reinforced concrete is ordinary concrete in which iron or steel rods or wire are imbedded. Reinforcement is required when the concrete is liable to be pulled or bent, as in beams, floors, posts, walls, or tanks, because, while concrete is as strong as stone masonry, neither of these materials has nearly so much strength in tension as in compression. Moreover, concrete alone, like any natural stone, is brittle, but by imbedding in it steel rods or other reinforcement, the cement adheres, and the metal binds the particles together so that the reinforced concrete is better adapted to withstand jar and impact. Even railway bridges are built, not only in arch form, like a stone arch, but in some cases like a steel girder bridge, with a flat reinforced concrete floor supported by horizontal beams of the same material.

"For reinforcement, plain round or square rods may be used, or rods with irregular surfaces, many of which are patented, so designed as to adhere more strongly to the concrete in which they are imbedded. For floor or roof slabs, steel is sometimes formed in sheets like wire lathing, or expanded metal, or woven wire fabric.

"An engineer or architect experienced in reinforced concrete design should be employed in preparing the plans for houses, barns, or other large structures, but by carefully following the directions and specifications in this book, small reinforced concrete construction may be safely undertaken by any cement worker. The table which follows gives the thickness and reinforcement of slabs, and the dimensions and reinforcement of reinforced concrete beams for a number of conditions which are liable to be met with in common practice. While the values are as low as should be adopted without knowing the local conditions, complete mathematical calculations of dimensions should be made for large structures, not only from the standpoint of safety, but also because of the saving in cost

of material which can be effected by fitting each member in its proper place.

"Rules which are written as foot-notes to the table, give very important directions.

"An invaluable rule in placing steel is to insert it in the face where the pull will come. Thus, in a beam or slab; it must be close to the bottom. In a wall to withstand earth pressure, it must be in the face nearest the earth. If, for example, a beam were designed according to the table, but the steel placed in the middle or top of the beam instead of in the bottom, it would certainly break under a very light load. There must be only enough concrete outside of the steel to protect it from rusting or fire. In floor or roof-slabs of small structures, this thickness should be ½ inch to ¾ inch below the bottom of the steel, and for beams, from 1 to 1½ inches.

"A typical beam with its connecting floor slabs, the concrete of both of which should be laid at the same operation, is shown in Fig. 5. It will be seen that the beam reinforcement consists of rods running lengthwise of the beam,—one-half or one-third of these rods being bent up about one-third way from each end and extending over the supports, as shown in Fig. 5,—and U-shaped bars or stirrups, which pass under the longitudinal rods and up on each side of the beam. The horizontal bars withstand the direct pull in the bottom of the beam due to bending when a load is placed upon it; the U-bars or stirrups and the bent-up bars prevent diagonal

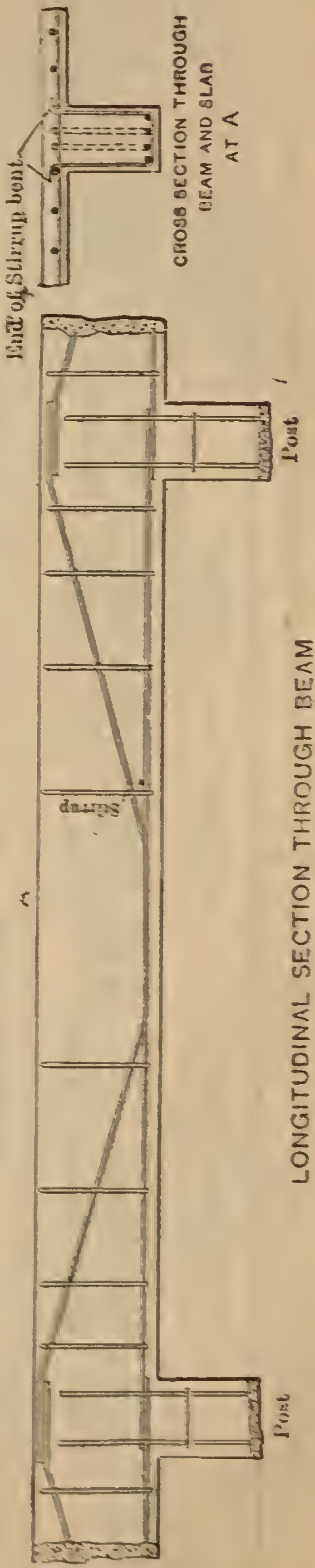


Fig. 5.—Typical Beam and Floor Slab.

cracks, which sometimes occur under loading, and the bars

TABLE FOR DESIGNING REINFORCED CONCRETE BEAMS AND SLABS.

Proportions of Concrete 1 : 2 : 4. [See important foot-note.]

Based upon a freely supported beam where $M = \frac{wl^2}{8}$. For continuous beams 25 per cent larger loads may be allowed.

Length or Span of Beam. Feet.	Distance apart of Beams. Feet.	Dimensions of Beam. Width. Inches.	Dimensions of Beam. Depth. Inches.	Dimensions of Beam. Depth below Steel. Inches.	Reinforcement of Beams. Number of Rods Required	Reinforcement of Beams. Diameter of Rods. Inches.	Reinforcement of Beams. Number of Stirrups at each end.	Reinforcement of Beams. Diameter of Stirrup Rods. Inches.	Reinforcement of Beams. Spacing* of Stirrups.	Thickness of Slabs. Total Thickness. Inches.	Thickness of Slabs. Depth below Steel. Inches.	Reinforcement of Slabs. Diameter of Rods. Inches.	Reinforcement of Slabs. Spacing of Rods. Inches.
Medium Heavy Floor Loading, 125 Pounds per Square Foot.													
8	4	6	13	$1\frac{1}{2}$	3	$\frac{1}{2}$	1	$\frac{5}{16}$	......	3	$\frac{3}{4}$	$\frac{5}{16}$	6
	6	7	15	$1\frac{1}{2}$	3	$\frac{9}{16}$	2	$\frac{5}{16}$	6	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{8}$	6
	8	8	17	$1\frac{1}{2}$	3	$\frac{5}{8}$	2	$\frac{3}{8}$	6	5	1	$\frac{1}{2}$	$7\frac{1}{2}$
10	4	7	14	$1\frac{1}{2}$	3	$\frac{1}{2}$	2	$\frac{5}{16}$	8	3	$\frac{3}{4}$	$\frac{5}{16}$	6
	6	9	17	$1\frac{1}{2}$	4	$\frac{9}{16}$	3	$\frac{5}{16}$	8	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{8}$	6
	8	9	20	2	4	$\frac{5}{8}$	3	$\frac{3}{8}$	8	5	1	$\frac{1}{2}$	$7\frac{1}{2}$
12	4	9	16	$1\frac{1}{2}$	4	$\frac{9}{16}$	2	$\frac{3}{8}$	8	3	$\frac{3}{4}$	$\frac{5}{16}$	6
	6	10	20	2	4	$\frac{5}{8}$	3	$\frac{3}{8}$	8	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{8}$	6
	8	11	22	2	4	$\frac{11}{16}$	4	$\frac{3}{8}$	8	5	1	$\frac{1}{2}$	$7\frac{1}{2}$
14	4	10	18	$1\frac{1}{2}$	4	$\frac{5}{8}$	2	$\frac{3}{8}$	8	3	$\frac{3}{4}$	$\frac{5}{16}$	6
	6	11	24	2	4	$\frac{3}{4}$	3	$\frac{3}{8}$	8	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{8}$	6
	8	13	24	2	4	$\frac{13}{16}$	4	$\frac{3}{8}$	8	5	1	$\frac{1}{2}$	$7\frac{1}{2}$
Light Floor Loading, 50 Pounds per Square Foot.													
8	4	5	10	$1\frac{1}{2}$	3	$\frac{3}{8}$	......	......	......	3	$\frac{3}{4}$	$\frac{1}{4}$	$5\frac{1}{2}$
	6	6	13	$1\frac{1}{2}$	3	$\frac{7}{16}$	......	......	......	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{16}$	7
	8	7	13	$1\frac{1}{2}$	3	$\frac{1}{2}$	......	......	......	4	$\frac{3}{4}$	$\frac{3}{8}$	$5\frac{1}{2}$
10	4	6	12	$1\frac{1}{2}$	3	$\frac{3}{8}$	......	......	......	3	$\frac{3}{4}$	$\frac{1}{4}$	$5\frac{1}{2}$
	6	7	15	$1\frac{1}{2}$	3	$\frac{9}{16}$	......	......	......	$3\frac{1}{2}$	$\frac{3}{4}$	$\frac{5}{16}$	7
	8	8	16	$1\frac{1}{2}$	3	$\frac{5}{8}$	......	......	......	4	$\frac{3}{4}$	$\frac{3}{8}$	$5\frac{1}{2}$

12	4 6 8	7 8 9	13 17 18	1½ 1½ 1½	3 3 4	½ ⅝ 9/16	¼ 5/16 5/16	3 3½ 4	¾ ¾ ¾	¼ 5/16 ⅜	5½ 7 5½
14	4 6 8	7 8 10	15 19 21	1½ 2 2	3 3 4	9/16 ⅝ 11/16	¼ 5/16 ⅜	3 3½ 4	¾ ¾ ¾	¼ 5/16 ⅜	5½ 7 5½
Roofs, 30 Pounds per Square Foot.											
8	4 6 8	5 6 7	10 11 12	1¼ 1¼ 1¼	3 3 3	⅜ 7/16 ½	¼ ¼ 5/16	2¾ 3 3¼	¾ ¾ ¾	3/16 ¼ ⅜	6 5½ 7½
10	4 6 8	6 7 8	12 13 14	1¼ 1½ 1½	3 3 3	7/16 ½ 9/16	¼ ¼ 5/16	2¾ 3 3¼	¾ ¾ ¾	3/16 ¼ ⅜	6 5½ 7½
12	4 6 8	7 7 8	13 16 17	1½ 1½ 1½	3 3 3	½ 9/16 ⅝	¼ 5/16 5/16	2¾ 3 3¼	¾ ¾ ¾	3/16 ¼ ⅜	6 5½ 7½
14	4 6 8	7 8 9	15 17 18	1½ 1½ 1½	3 3 3	9/16 ⅝ 11/16	¼ 5/16 5/16	2¾ 3 3¼	¾ ¾ ¾	3/16 ¼ ⅜	6 5½ 7½

1. Bend diagonally upwards, one rod in three, or two rods in four from ¼ points in beam to top of beam and over supports. (See Fig. 5.)
2. Stirrups are made U-shaped with bent ends. (See Fig. 5A.)
3. Slab reinforcement is placed at right angles to supporting beams.
   Cross reinforcement of slightly smaller rods or same rods farther apart is also placed in slabs parallel to beams.
4. Wire fabric or expanded metal mesh may be substituted for rods in the slabs, provided the area of section of metal is kept the same as the rods.
5. Cinder concrete should not be used for beams.
6. Cinder concrete may be used for roof slabs if thickness is increased one inch.
7. After setting 30 days, test two of the slabs and one beam by loading two panels with sand to depth of:
   18 inches deep for heavy floor loading;
   8 inches deep for light floor loading;
   5 inches deep for roof loading.

* Place first stirrup in every case 6 inches from support.

placed just above the bottom surface at the center of the span and then bent upward over the supports, as shown by Fig. 5.

"Maximum size of broken stone or gravel should not be over 1 inch diameter in order to pass between and under the steel rods. Consistency of concrete should be like heavy cream."

The ratio of cement to the aggregate for use in reinforced concrete should be about 5 to 1 for ordinary beams and floors and 4 to 1 for columns, etc.

Metal Reinforcements for Concrete.—Fig. 6 shows a number of metal reinforcements now used by various companies and engineers for reinforcing concrete.

The twisted bar shown is used by the Ransome System, and is one of the first methods of reinforcement used in this country, it having been patented and used by Mr. Ransome in San Francisco in 1884.

A twisted bar of slightly different se tion is made by the Buffalo Steel Co., Tonawanda, N. Y. This bar before being twisted is a square section having a bead on each corner.

The Kahn bar is a square bar rolled with a web or flange on opposite corners. This flange is cut and turned up as shown, the short pieces of the flange acting as member of a truss when bedded in the concrete. This bar is used by the Trussed Concrete Steel Co. of Detroit. This company also manufactures the "Truss-cone" bar, as shown.

THE "UNIT" SYSTEM.—In this system the different reinforcing members of a beam are bolted and fastened together and put in place as a unit; hence its name. It is controlled by the Unit Concrete Steel Frame Co., Philadelphia, Pa.

The "Universal" bar is a rectangular bar rolled with pockets or depressions on its face into which the concrete is forced, and which gives it great adhesive power. It is manufactured by the Rogers-Hall Company, Warren, Pa.

The Cummings system shown is the invention of Robt. A. Cummings, Pittsburg, Pa. Its different members are round and flat rods bent to the shapes shown.

The Johnson bar is controlled by the St. Louis Expanded Metal Company. It is a square bar with depressions rolled in it as shown, and which give a mechanical bond between the iron and concrete.

The Thatcher bar is a rolled bar as shown, with raised portions to engage in the concrete. It is manufactured by the

Concrete Steel Engineering Co., New York. This company also controls the "Diamond Bar," a round bar having a series of raised corrugations.

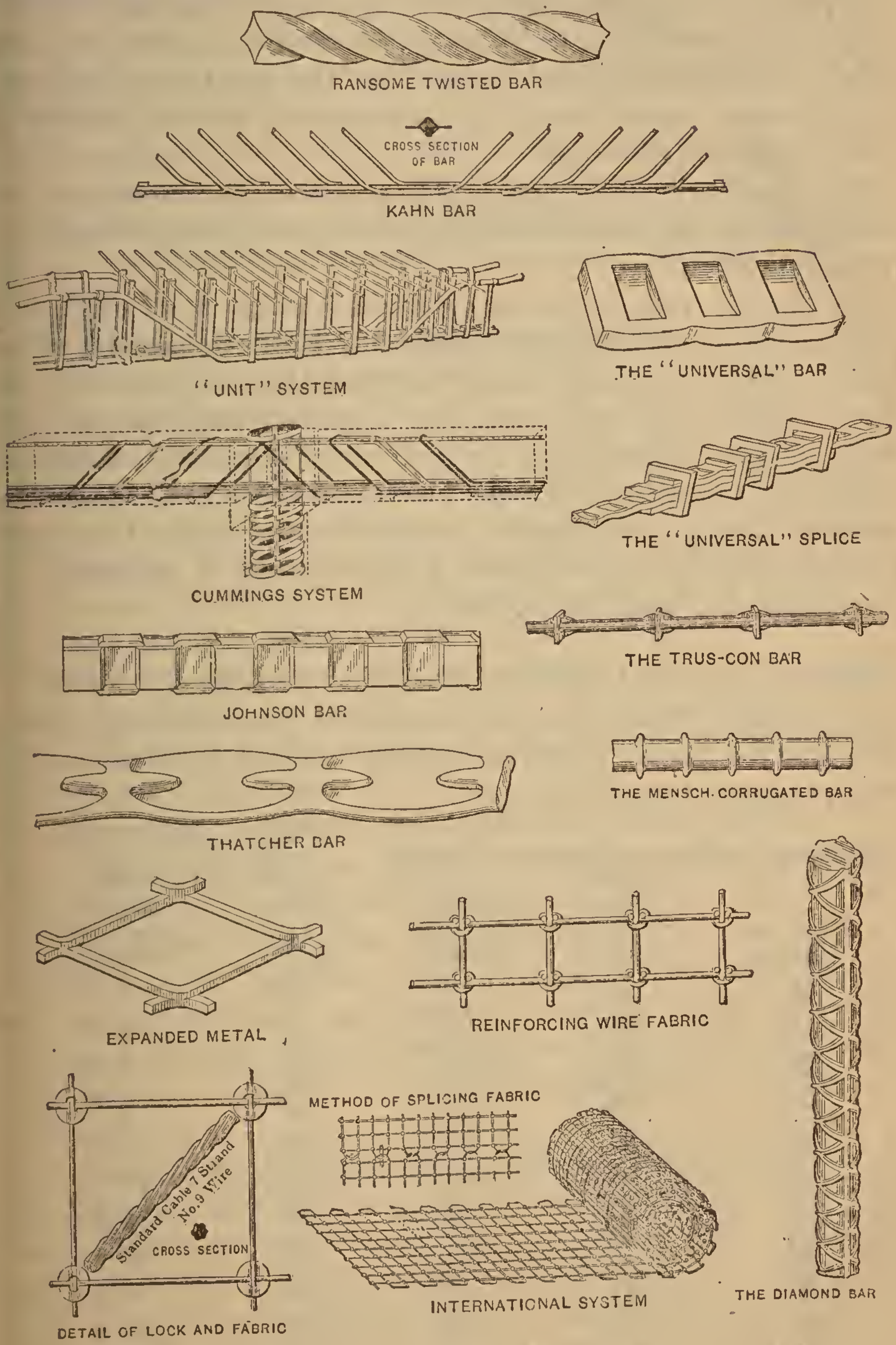


Fig. 6.—Various Types of Metal Reinforcing for Concrete.

The Mensch Corrugated bar is patented and manufactured by L. J. Mensch, Chicago. It is a round section having raised rings or corrugations at regular intervals.

Expanded Metal.—This method of reinforcing is controlled largely by the Associated Expanded Metal Companies, which have offices in all of the large cities. The General Fire-proofing Company, Youngstown, Ohio, also manufacture expanded metal.

Wire Reinforcement.—There are several makes of wire fabric reinforcement for concrete on the market. The reinforcing wire fabric shown is manufactured by the American Wire Fence Co., Chicago.

The International System is also a wire reinforcement, and is manufactured by the International Fence and Fire-proofing Co., Columbus, Ohio.

Reinforcing rods which have a mechanical bond with the concrete are superior to the plain rods, which depend for their bond entirely on the adhesion between the rod and the concrete. Plain rods will often lose a considerable amount of their adhesive strength by being struck by careless workmen before the concrete is entirely hard and which will break the adhesion along considerable length of the rod. Fig. 134, p. 203, shows the mechanical bond between a deformed or corrugated bar and the concrete.

WEIGHT OF REINFORCED CORCRETE IN SLABS OR BEAMS.

Taylor and Thompson have prepared the following table, using 150 lbs. per cu. ft. for cinder concrete and 4 lbs. per cu. ft. for 1 per cent of reinforced steel:

Weight of Reinforced Slabs per Square Foot.			Weight of Reinforced Beam 1 In. Wide per Foot of Length.	
Thickness. Inches.	Stone Concrete. Pounds.	Cinder Concrete. Pounds.	Depth of Beam.	Stone Concrete. Pounds.
2	26	19	6	6.4
2½	32	24	7	7.5
3	38	29	8	8.6
3½	45	34	9	9.6
4	51	39	10	10.7
4½	58	43	12	12.8
5	64	48	14	15.0
5½	70	53	16	17.1
6	77	58	18	19.2
7	90	68	20	21.4
8	103	77	25	26.8
9	115	87	30	32.1
10	128	97	35	37.4

Placing Concrete Around Metal Reinforcing.—Great care and judgment must be exercised when placing concrete around reinforcing rods, or metal reinforcing of any kind. The rods must be put in at the point designated by the engineer on the drawings, and they must be bedded solidly in the concrete, and all parts of the rod must have contact and adhesion with the concrete.

When the rods or metal reinforcing is put in place before any concrete is deposited, care must be taken not to knock them out of position and to see that the concrete is filled solid up to the bottom of the rod before any concrete is put on top of it.

Expanded metal and woven-wire floor-slab reinforcing is usually stretched across the forms before any concrete is deposited, then a thin layer (about an inch thick) of concrete is spread uniformly over the metal and with a hook or the corner of the shovel the metal is pulled up through the concrete, leaving this thin layer on the forms with the metal laying on top. Then the rest of the concrete is deposited and rammed in place. This places the metal reinforcement about three quarters of an inch from the bottom of the concrete slab.

Unless care is taken to bring the metal up through this thin layer of concrete the metal will show on the underside of the slab, and this is sufficient cause for rejection under the building laws of the larger cities.

Rules for Reinforced Concrete Construction.—The following regulations for reinforced concrete-steel construction were issued by the Bureau of Buildings of the Borough of Manhattan, Greater New York, September 9, 1903:

1. The term "concrete-steel" in these regulations shall be understood to mean an approved concrete mixed reinforced by steel of any shape, so combined that the steel will take up the tensional stresses and assist in the resistance to shear.

2. Concrete-steel construction will be approved only for buildings which are not required to be fire-proof by the Building Code, unless satisfactory fire and water tests shall have been made under the supervision of this bureau. Such tests shall be made in accordance with the regulations fixed by this bureau and conducted as nearly as practicable in the same manner as prescribed for fire-proof floor fillings in Section 106 of the Building Code. Each company offering a system of

concrete-steel construction for fire-proof buildings must submit such construction to a fire and water test.

3. Before permission to erect any concrete-steel structure is issued complete drawings and specifications must be filed with the superintendent of buildings, showing all details of the construction, the size and position of all reinforcing-rods, stirrups, etc., and giving the composition of the concrete.

4. The execution of work shall be confided to workmen who shall be under the control of a competent foreman or superintendent.

5. The concrete must be mixed in the proportions of one of cement, two of sand, and four of stone or gravel; or the proportions may be such that the resistance of the concrete to crushing shall not be less than 2000 pounds per square inch after hardening for 28 days. The tests to determine this value must be made under the direction of the superintendent of buildings. The concrete used in concrete-steel construction must be what is usually known as a "wet" mixture.

6. Only high-grade Portland cements shall be permitted in concrete-steel construction. Such cements, when tested neat, shall, after one day in air, develop a tensile strength of at least 300 pounds per square inch; and after one day in air and six days in water shall develop a tensile strength of at least 500 pounds per square inch; and after one day in air and 27 days in water shall develop a tensile strength of at least 600 pounds per square inch. Other tests, as to fineness, constancy of volume, etc., made in accordance with the standard method prescribed by the American Society of Civil Engineers' Committee, may from time to time be prescribed by the superintendent of buildings.

7. The sand to be used must be clean, sharp, grit sand free from loam or dirt, and shall not be finer than the standard sample of the Bureau of Buildings.

8. The stone used in the concrete shall be a clean, broken trap-rock or gravel of a size that will pass through a $\frac{3}{4}$-inch ring. In case it is desired to use any other material or other kind of stone than that specified, samples of same must first be submitted to and approved by the superintendent of buildings.

9. The steel shall meet the requirements of Section 21 of the Building Code.

10. Concrete-steel shall be so designed that the stresses in the concrete and the steel shall not exceed the following limits:

	Pounds per Square Inch.
Extreme fibre stress on concrete in compression	500
Shearing stress in concrete	50
Concrete in direct compression	350
Tensile stress in steel	16,000
Shearing stress in steel	10,000

11. The adhesion of concrete to steel shall be assumed to be not greater than the shearing strength of the concrete.

12. The ratio of the moduli of elasticity of concrete and steel shall be taken as 1 to 12.

13. The following assumption shall guide in the determination of the bending moments due to the external forces: Beams and girders shall be considered as simply supported at the ends, no allowance being made for the continuous construction over supports. Floor plates, when constructed continuous and when provided with reinforcement at top of plate over the supports, may be treated as continuous beams, the bending moment for uniformly distributed loads being taken at not less than $\frac{WL}{10}$; the bending moment may be taken as $\frac{WL}{20}$ in the case of square floor plates which are reinforced in both directions and supported on all sides. The floor plate to the extent of not more than ten times the width of any beam or girder may be taken as part of that beam or girder in computing its moment of resistance.

14. The moment of resistance of any concrete-steel construction under transverse loads shall be determined by formulas based on the following assumptions:

a. The bond between the concrete and steel is sufficient to make the two materials act together as a homogeneous solid.

b. The strain in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

c. The modulus of elasticity of the concrete remains constant within the limits of the working stresses fixed in these regulations.

From these assumptions it follows that the stress in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

The tensile strength of the concrete shall not be considered.

15. When the shearing stresses developed in any part of a construction exceed the safe working-strength concrete, as

fixed in these regulations, a sufficient amount of steel shall be introduced in such a position that the deficiency in the resistance to shear is overcome.

16. When the safe limit of adhesion between the concrete and steel is exceeded, some provision must be made for transmitting the strength of the steel to the concrete.

17. Concrete-steel may be used for columns in which the ratio of length to least side or diameter does not exceed 12. The reinforcing-rods must be tied together at intervals of not more than the least side or diameter of the column.

18. The contractor must be prepared to make load tests on any portion of a concrete-steel construction, within a reasonable time after erection, as often as may be required by the superintendent of buildings. The tests must show that the construction will sustain a load of three times that for which it is designed without any sign of failure.

Approved September 9, 1903.

HENRY S. THOMPSON,

Superintendent of Buildings for the Borough of Manhattan.

CONCRETE-FLOOR CONSTRUCTION.—There are a number of different systems of concrete-floor construction and fireproofing, each being controlled by a different company, and it will be the duty of any one in charge of cement and concrete construction to keep himself posted regarding all the different systems, so that when one is put under his supervision he can readily judge if it is being done right.

A system of floor construction may be perfectly reliable when properly constructed; but with poor material or workmanship it may result in a weak floor.

Cinder concrete reinforced in different ways with steel is the usual construction, and in work of this kind all the materials should be the best, and the reinforcing and workmanship done in a proper manner.

The proportions for a good cinder concrete are one part cement, two parts sand, and five parts cinders.

Regarding fire-proof floors the New York Building Code says:

Sec. 106. *Fire-proof Floors.*—Fire-proof floors shall be constructed with wrought-iron or steel floor-beams so arranged as to spacing and length of beams that the load to be supported by them, together with the weights of the materials used in the construction of the said floors, shall not cause a greater deflection of the said beams than one-thirtieth of an

inch per foot of span under the total load; and they shall be tied together at intervals of not more than eight times the depth of the beam. Between the wrought-iron or steel floor-beams shall be placed brick arches springing from the lower flange of the steel beams. Said brick arches shall be designed with a rise to safely carry the imposed load, but never less than one and one-quarter inches for each foot of span between the beams, and they shall have a thickness of not less than four inches for spans of five feet or less and eight inches for spans over five feet, or such thickness as may be required by the Board of Buildings. Said brick arches shall be composed of good, hard brick or hollow brick of ordinary dimensions laid to a line on the centres, properly and solidly bonded, each longitudinal line of brick breaking joints with the adjoining lines in the same ring and with the ring under it when more than a four-inch arch is used. The brick shall be well wet and the joints filled in solid with cement mortar. The arches shall be well grouted and properly keyed. Or the space between the beams may be filled in with hollow-tile arches of hard-burnt clay or porous terra-cotta of uniform density and hardness of burn. The skew-backs shall be of such form and section as to properly receive the thrust of said arch; and the said arches shall be of a depth and sectional area to carry the load to be imposed thereon, without straining the material beyond its safe working load, but said depth shall not be less than one and three-quarter inches for each foot of span. not including any portion of the depth of the tile projecting below the under side of the beams, a variable distance being allowed of not over six inches in the span between the beams, if the soffits of the tile are straight; but if said arches are segmental, having a rise of not less than one and one-quarter inches for each foot of span, the depth of the tile shall be not less than six inches. The joints shall be solidly filled with cement mortar as required for common brick arches and the arch so constructed that the key block shall always fall in the central portion. The shells and webs of all end construction blocks shall abut, one against another. Or the space between the beams may be filled with arches of Portland-cement concrete, segmental in form, and which shall have a rise of not less than one and one-quarter inches for each foot of span between the beams. The concrete shall be not less than four inches in

thickness at the crown of the arch and shall be mixed in the proportions required by Section 18 of this Code. These arches shall in all cases be reinforced and protected on the under side with corrugated or sheet steel, steel ribs, or metal in other forms weighing not less than one pound per square foot and having no openings larger than three inches square. Or between the said beams may be placed solid or hollow burnt-clay, stone, brick, or concrete slabs in flat or curved shapes, concrete or other fire-proof composition, and any of said materials may be used in combination with wire cloth, expanded metal wire strands, or wrought-iron or steel bars; but in any such construction and as a precedent condition to the same being used, tests shall be made as herein provided by the manufacturer thereof under the direction and to the satisfaction of the Board of Buildings, and evidence of the same shall be kept on file in the Department of Buildings, showing the nature of the test and the result of the test. Such tests shall be made by constructing within inclosure walls a platform consisting of four rolled steel beams, ten inches deep, weighing each twenty-five pounds per lineal foot, and placed four feet between the centres, and connected by transverse tie-rods, and with a clear span of fourteen feet for the two interior beams and with the two outer beams supported on the side walls throughout their length, and with both a filling between the said beams and a fire-proof protection of the exposed parts of the beams of the system to be tested, constructed as in actual practice, with the quality of material ordinarily used in that system and the ceiling plastered below, as in a finished job; such filling between the two interior beams being loaded with a distributed load of one hundred and fifty pounds per square foot of its area and all carried by such filling; and subjecting the platform so constructed to the continuous heat of a wood fire below, averaging not less than seventeen hundred degrees Fahrenheit for not less than four hours, during which time the platform shall have remained in such condition that no flame will have passed through the platform or any part of the same, and that no part of the load shall have fallen through, and that the beams shall have been protected from the heat to the extent that after applying to the under side of the platform at the end of the heat test a stream of water directed against the bottom of the platform and discharged through a one and one-eighth inch

nozzle under sixty pounds pressure for five minutes, and after flooding the top of the platform with water under low pressure, and then again applying the stream of water through the nozzle under the sixty pounds pressure to the bottom of the platform for five minutes, and after a total load of six hundred pounds per square foot uniformly distributed over the middle bay shall have been applied and removed, after the platform shall have cooled, the maximum deflection of the interior beams shall not exceed two and one-half inches. The Board of Buildings may from time to time prescribe additional or different tests than the foregoing for systems of filling between iron or steel floor-beams, and the protection of the exposed parts of the beams. Any system failing to meet the requirements of the test of heat, water, and weight as herein prescribed shall be prohibited from use in any building hereafter erected. Duly authenticated records of the tests heretofore made of any system of fire-proof floor filling and protection of the exposed parts of the beams may be presented to the Board of Buildings, and if the same be satisfactory to said Board, it shall be accepted as conclusive. No filling of any kind which may be injured by frost shall be placed between said floor-beams during freezing weather, and if the same is so placed during any winter month, it shall be temporarily covered with suitable material for protection from being frozen. On top of any arch, lintel, or other device which does not extend to and form a horizontal line with the top of the said floor-beams, cinder concrete or other suitable fire-proof material shall be placed to solidly fill up the space to a level with the top of the said floor-beams, and shall be carried to the under side of the wood floor-boards in case such be used. Temporary centring when used in placing fire-proof systems between floor-beams shall not be removed within twenty-four hours or until such time as the mortar or material has set. All fire-proof floor systems shall be of sufficient strength to safely carry the load to be imposed thereon without straining the material in any case beyond its safe working load. The bottom flanges of all wrought-iron or rolled-steel floor and flat roof beams, and all exposed portions of such beams below the abutments of the floor-arches, shall be entirely encased with hard-burnt clay, porous terra-cotta, or other fire-proof material allowed to be used for the filling between the beams under the provisions of this section, such incasing material to be properly secured to the beams.

The exposed sides and bottom plates or flanges of wrought-iron or rolled-steel girders supporting iron or steel floor-beams, or supporting floor-arches or floors, shall be entirely incased in the same manner. Openings through fire-proof floors for pipes, conduits, and similar purposes shall be shown on the plans. After the floors are constructed no opening greater than eight inches square shall be cut through said floors unless properly boxed or framed around with iron. And such openings shall be filled in with fire-proof material after the pipes or conduits are in place.

Sec. 107. *Incasing Interior Columns.*—All cast-iron, wrought-iron, or rolled-steel columns, including the lugs and brackets on same, used in the interior of any fire-proof building, or used to support any fire-proof floor, shall be protected with not less than two inches of fire-proof material, securely applied. The extreme outer edge of lugs, brackets, and similar supporting metal may project to within seven-eighths of an inch of the surface of the fireproofing.

Concrete Piles.—Concrete piles are now being used with good success. One form of pile, Fig. 7, is made by casting the concrete and reinforcing it with steel. After they are thoroughly set and dry they are driven like an ordinary pile, except a special cap is used to prevent shattering the head of the pile. Another type called the Raymond, Fig. 8, has been used, which consists of a thin shell of metal with a strong core inside to take the shock of driving; after the shell and core are driven to the desired depth, the core, which is collapsible, is withdrawn and the shell filled with concrete. These piles are usually made with a large taper, as this gives them a large bearing area and permits the core to be taken out easily; about 6 inches at the bottom and 20 inches at the top is the usual size. By a test made in Chicago, one of these piles carried as much as three wooden ones having the same diameter at the point. And at Schenectady, N. Y., they were loaded with from 32,000 to 48,000 pounds per pile without settlement. The soil was a soft fill.

Figs. 9 and 10 show what is known as the Simplex Pile. A wrought-iron or steel cylinder with a concrete point is driven like any ordinary pile, then the reinforcing is put inside the shell and it is filled with concrete, the shell being drawn as the concrete is filled up.

There have been used in the building of the wharves in San Francisco harbor concrete piles made by forcing down a shell

of wood 2 to 3 feet in diameter and after pumping it out filling it with concrete. The wooden shell is left on and by the time it decays or the teredo has destroyed it the concrete is hard and a concrete pile is the result. (See page 50 as to mixing concrete, etc.)

FIG. 7.

FIG. 8.

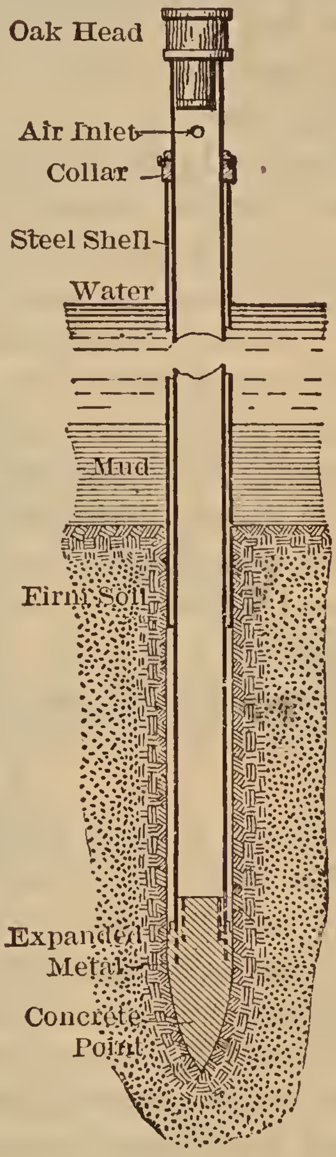


FIG. 9.

FIG 10.

Concrete Piles.

CONCRETE CAPPING.—Concrete, which is much used for capping of piles, is one of the best materials for this purpose, for when it is put in properly it forms one continuous stone having a solid bed on all the piles. The piles should be cut off square and the dirt cleaned away so the concrete can be

rammed around and between the piles to a depth of a foot or more.

Concrete capping is very often reinforced with steel beams or railroad rails. These should be free from rust or dirt and coated with asphalt, or close attention given to covering them with a coat of cement mortar or concrete. If the concrete is rammed solid enough around the beams it will in itself form a protection, but this takes much care and time and will require the strict attention of the superintendent. The New York building code says:

"The tops of all piles shall be cut off below the lowest water line. When required, concrete shall be rammed down in the interspaces between the heads of the piles to a depth and thickness not less than 12 inches and for 1 foot in width outside the piles. Where ranging and capping timbers are laid on the piles for foundations, they shall be of hard wood not less than 6 inches thick and properly joined together, and their tops laid below the lowest water line. Where metal is incorporated in or forms part of the foundation it shall be thoroughly protected from rust by paint, asphaltum, concrete, or by such materials and in such manner as may be approved by the Commissioner of Buildings. When footings of iron or steel for columns are placed below the water level, they shall be similarly coated or enclosed in concrete for preservation from rust."

When concrete is used for capping it should be allowed to harden before any additional weight is built upon it, or the ground may give between the piles and the piles will act like a series of punches forcing their way up through the concrete.

Wood Forms.—Pine, spruce, or fir are the best woods to use for the construction of forms for concrete work. Some of the other woods, especially California red wood or chestnut, will stain the finished surface of the concrete.

The wood for forms should not be too dry or it will swell and warp when the wet concrete is put against it. The planking should be 2 inches thick, surfaced on one side to an even thickness, of about 1¾ inches, and the edges beveled, as shown by Fig. 11. This will make a tight joint, and allow the planking to swell a little without warping.

The forms for concrete should always be made strong and rigid, so they will withstand the pressure of the wet concrete.

One of the most important points of a good piece of concrete work is the building of forms. When there are to be any recesses or chases in the finished concrete, cores must be put in to form these chases, etc., and when the face of the

FIG. 11.—Beveled Planks for Forms.

concrete is to be laid off in blocks in imitation of stonework with rusticated joints, wood strips must be put in place to form these rustications, as shown by Fig. 130, p. 183.

To make a smooth surface keep the dressed side of the planking next the concrete and to keep them from adhering to the

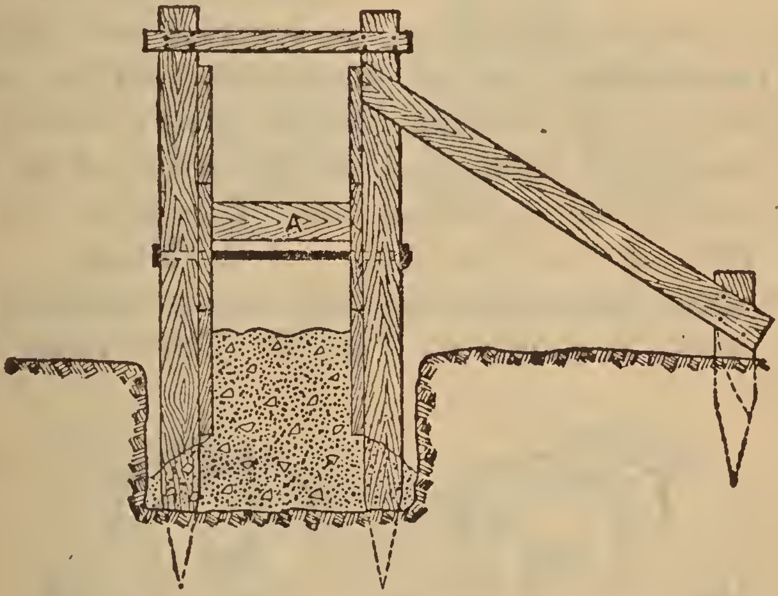


FIG. 12.—Form for Foundation Walls.

concrete they can be given a coat of crude oil, or soap dissolved in water, just before depositing the concrete. If it is intended to allow the concrete to harden for about two weeks before removing the forms, it will not be necessary to oil them, as the hard concrete will not stick.

For ordinary walls, foundations, etc., forms can be built, as shown by Fig. 12. 2″×4″ or 2″×6″ uprights, spaced about 2 feet apart for 1-inch planking, or not over 4 feet for 2-inch planking.

These uprights can be pointed and driven in the ground as shown, then braced and stayed so as to hold them in position; then the planking put in place.

If a spread footing is desired keep the planking up as shown, allowing the concrete to spread out on the sides to form a footing, as shown.

For walls over 3 feet in heigth bolts should be used, as shown, to keep the forms from spreading. A spreader, as at *A*, Fig. 12, should be cut in, and the bolt tightened enough to hold this spreader in place, then when the concrete is tamped into place it will cause pressure enough to loosen the spreader, which can then be taken out.

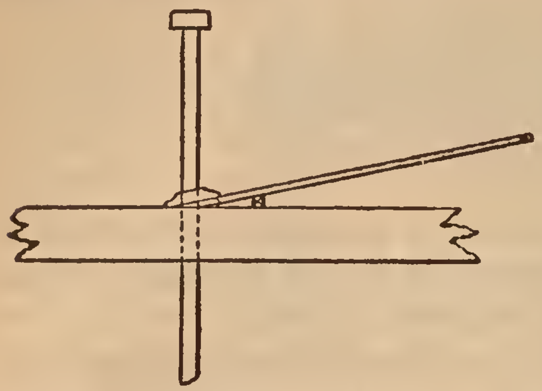


FIG. 13.—Withdrawing Bolt fro m Forms.

The bolt should be greased with oil, or rubbed with soap, or wrapped with paper, so it can be easily taken out of theconcrete and the hole filled with cement. It is a good idea to have a thread and nut on both ends of the bolts, then the forms can all be taken off the bolts before they are driven out. This saves the time of trying to take out the bolts along with the forms.

To withdraw tight bolts tilt the washer and use a small bar as a lever, as shown by Fig. 13. The washer will bind

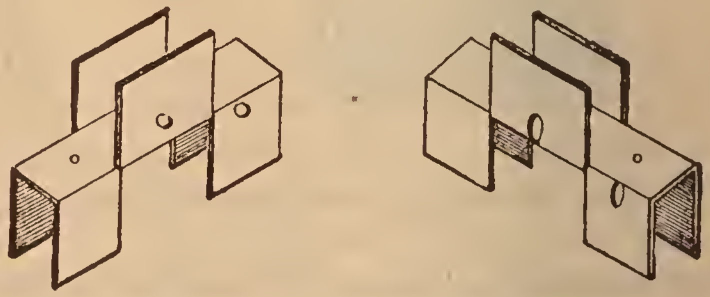


FIG 14.—Sullivan Plank Holders.

on the bolt and not slip; as the bolt is withdrawn, drop the washer down, taking a new "bite."

Metal form or plank-holders are now manufactured, and which greatly facilitate the building of forms for concrete work.

Fig. 14 shows a pressed-steel holder and Figs. 15 to 17 show it being used in walls, with bolts run through to prevent spreading.

Figs. 16 and 17 show how it is used in angles, etc. This

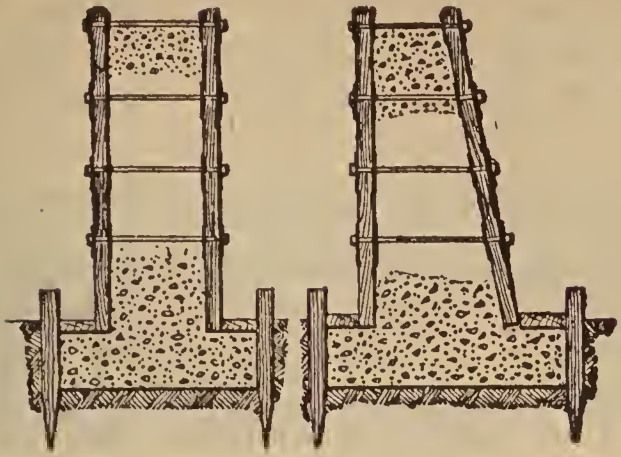


Fig. 15.—Sullivan Plank-holder as Used for Walls.

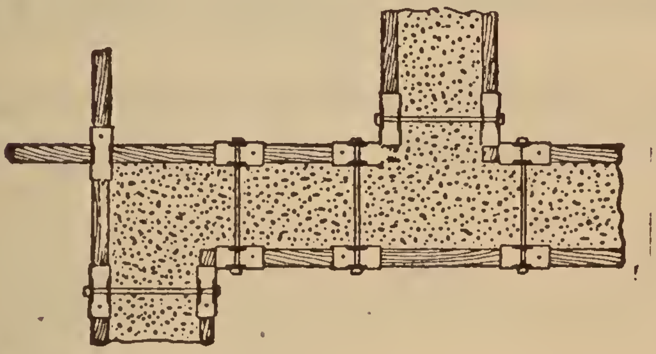


Fig. 16.—Sullivan Plank-holder at Internal Angles.

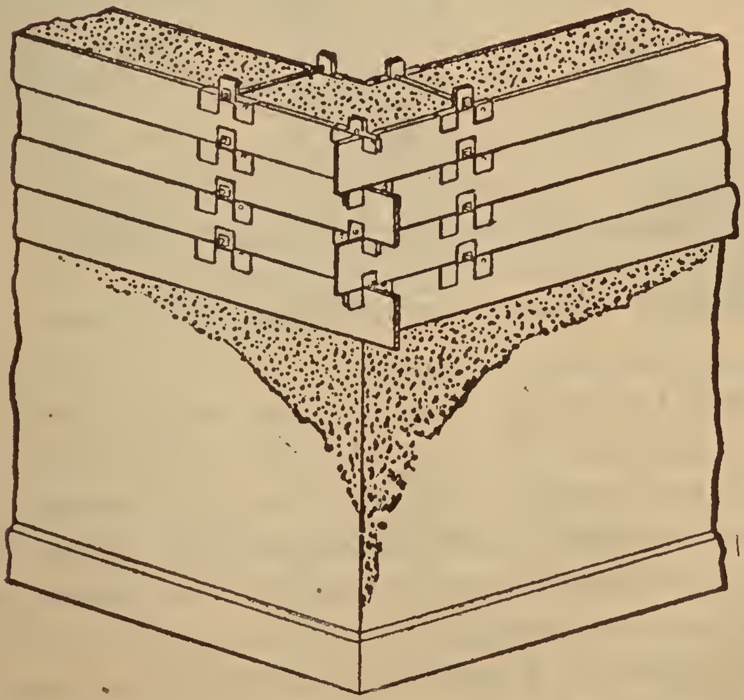


Fig. 17.—Forming Corner with Sullivan Plank-holder.

plank-holder is manufactured by J. H. Sullivan, Grand Rapids, Mich.

FORMS OR CENTERING FOR FLOOR CONSTRUCTION.—Fig. 18

FIG. 18.—Floor Centering.

shows a form or centering as generally used for floor construction.

A stringer is run across the top of the floor beams and by means of hook bolts another stringer is suspended at the desired

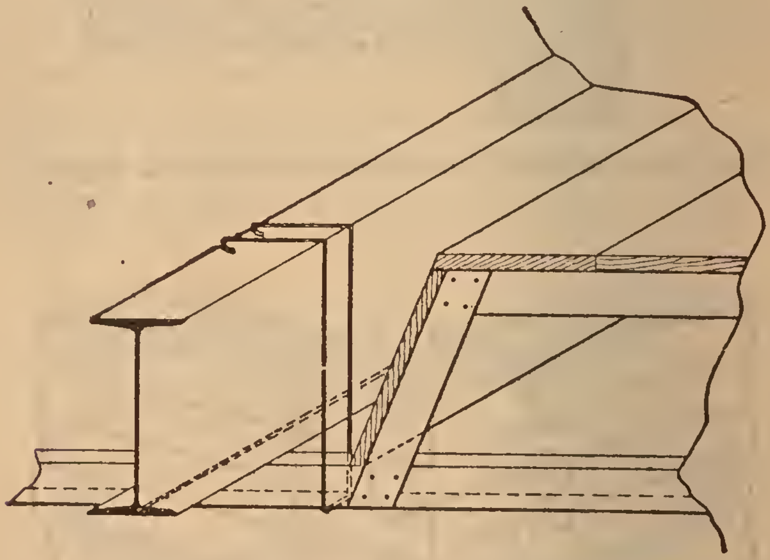


FIG. 19.—Hanging Centering from Floor Beams.

distance below the beams, then the centering is built in place as shown.

Fig. 19 shows another method of supporting floor centering by means of stirrups. The stirrups are made from $\frac{1}{4}''$ round iron and hooked over the top of the beams as shown, to carry the lower stringer.

When the centering is removed the stirrups are cut off flush with the underside of the concrete.

When the soffits of the beams are not to be covered with

concrete the centering can be built, as shown by Fig. 20, the ribs or cross pieces resting on the lower flange of the beams as shown.

The plank forming the mould for the haunch of the beam is notched down over the lugs on the end of the ribs, as shown,

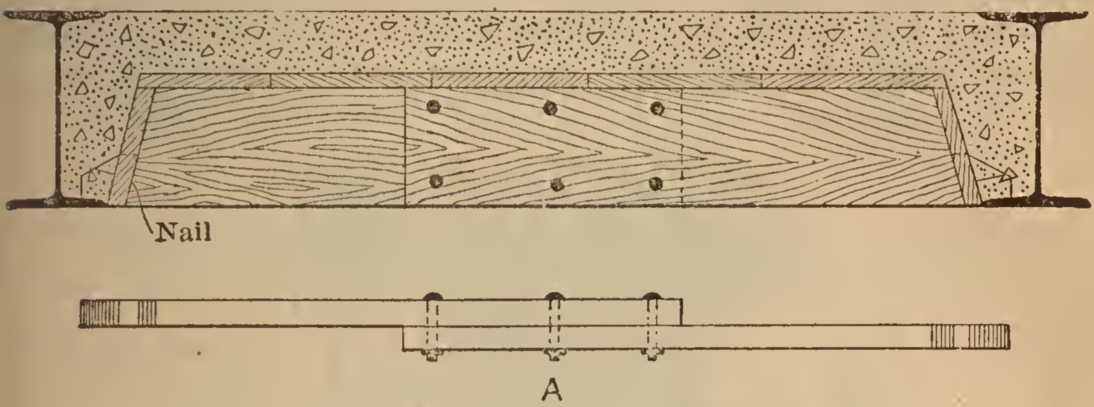


FIG. 20.—Centering for Floor Slabs.

and a nail driven through the rib, as indicated, to take the strain on the part of the plank notched over the rib, and prevent it being split off when the concrete is rammed in place, or if desired, blocks can be nailed on the side of the ribs for the same purpose.

The ribs should be made in two pieces and bolted together, as shown at *A*, Fig. 20. In this way they are easily removed by

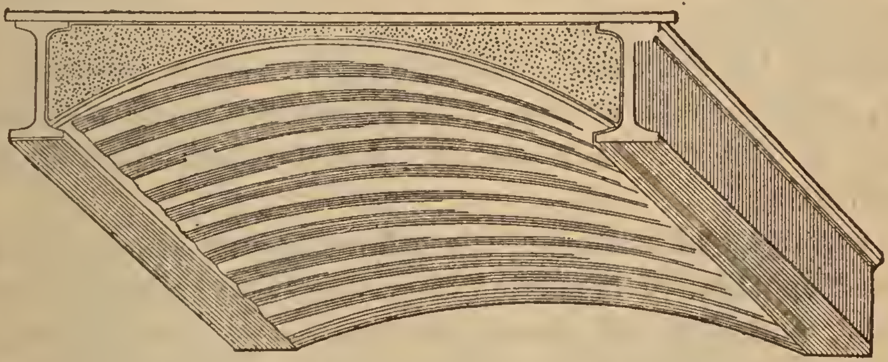


FIG. 21.—Arch with Corrugated Sheet Metal Centering.

taking out the bolts, and can also be adjusted to different spacing of beams.

Fig. 21 shows a similar floor arch with corrugated metal centering, and which is left in place when the floor is finished.

A floor arch with arches and centering of this kind can be built as cheap as that shown by Fig. 20, and is a much better and stronger arch.

Fig. 22 shows a hanger for floor centering, patented by J. H.

Dousman, Kansas City, Mo. Special nuts are made to lay on the lower flange of the beams as shown. When the centering is taken down the bolts are taken out and the nuts are left in the concrete.

Then by providing new nuts the bolts can be used over again.

Forms for beams and flat slabs of any considerable span should always be built with a camber to the soffit or bottom,

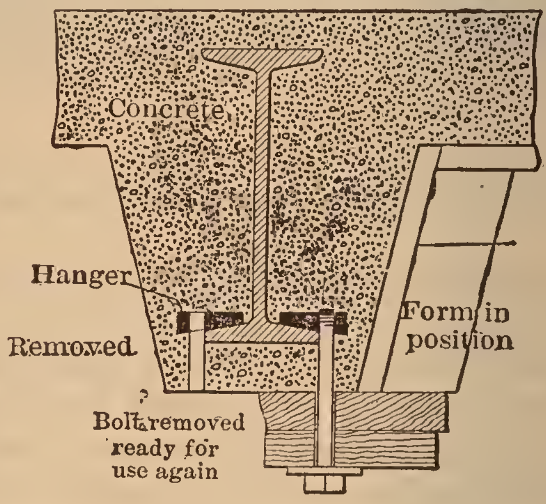


Fig. 22.—"Dousman" Hanger for Floor Centering.

so that if there is any sag to the form it will not show a sag in the finished concrete.

Heavy Centering.—Centering for large arches, bridge work, etc., must be erected with great care, so it will carry the weight of the wet concrete to be deposited upon it without much settling.

As examples of centering the following cuts are given: Fig. 23 shows a method of centering that has been used for a span of 50 feet, and Fig. 24 shows the centering used by the Short Line R. R. in building concrete spans of 60 feet over the Pennypack Creek, near Philadelphia.

Fig. 25 shows the centering used in the 150-foot spans of the Connecticut Avenue Bridge, Washington, D. C. The work was carried upon each side of the arch uniformly, and the top was loaded temporarily, so the settlement of the centering would take place before the wet concrete was placed in the centre of the span.

The settlement in the centering of these arches at the centre run as high as $3\frac{1}{2}$ inches.

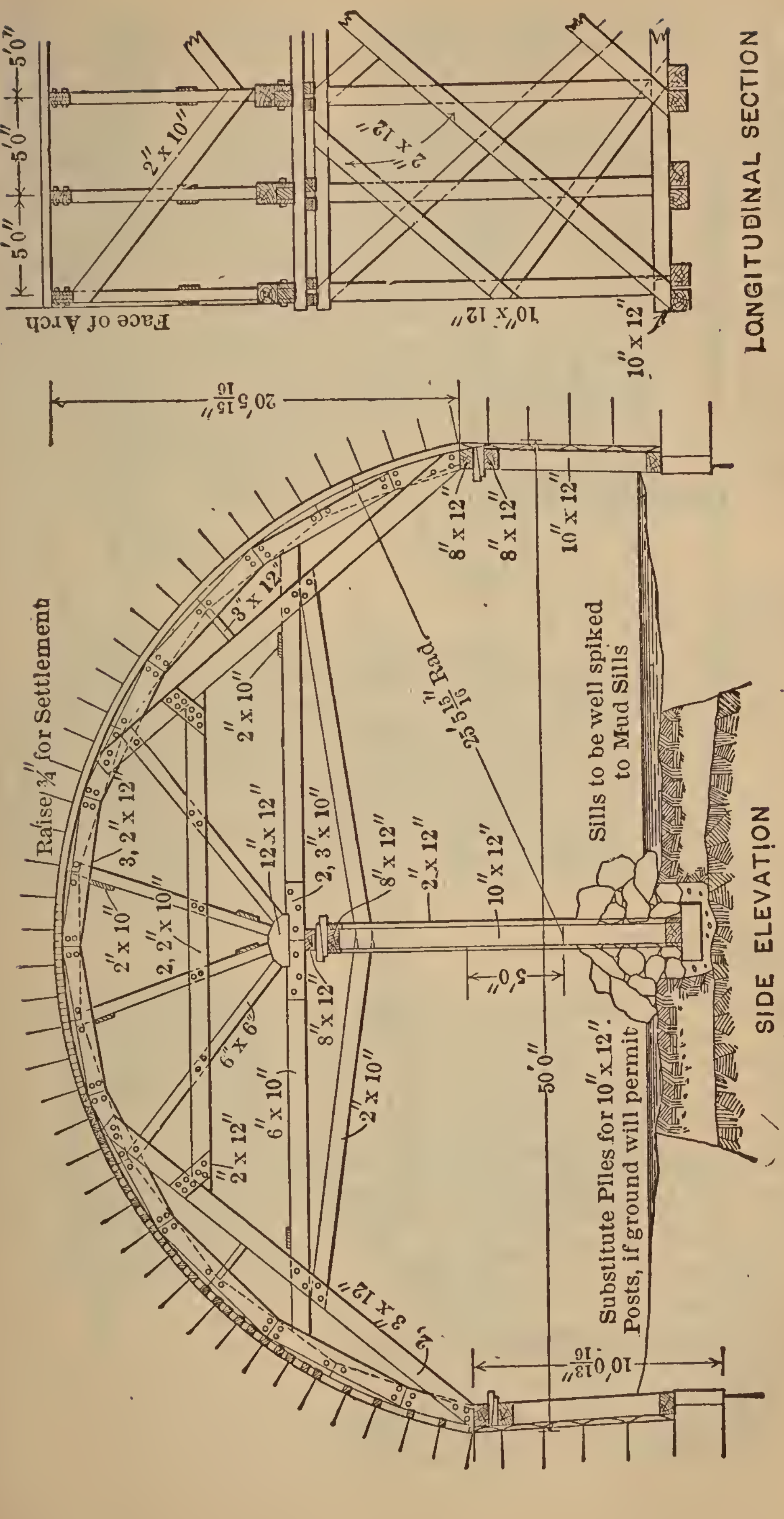


Fig. 23.—Method of Arch Centering.

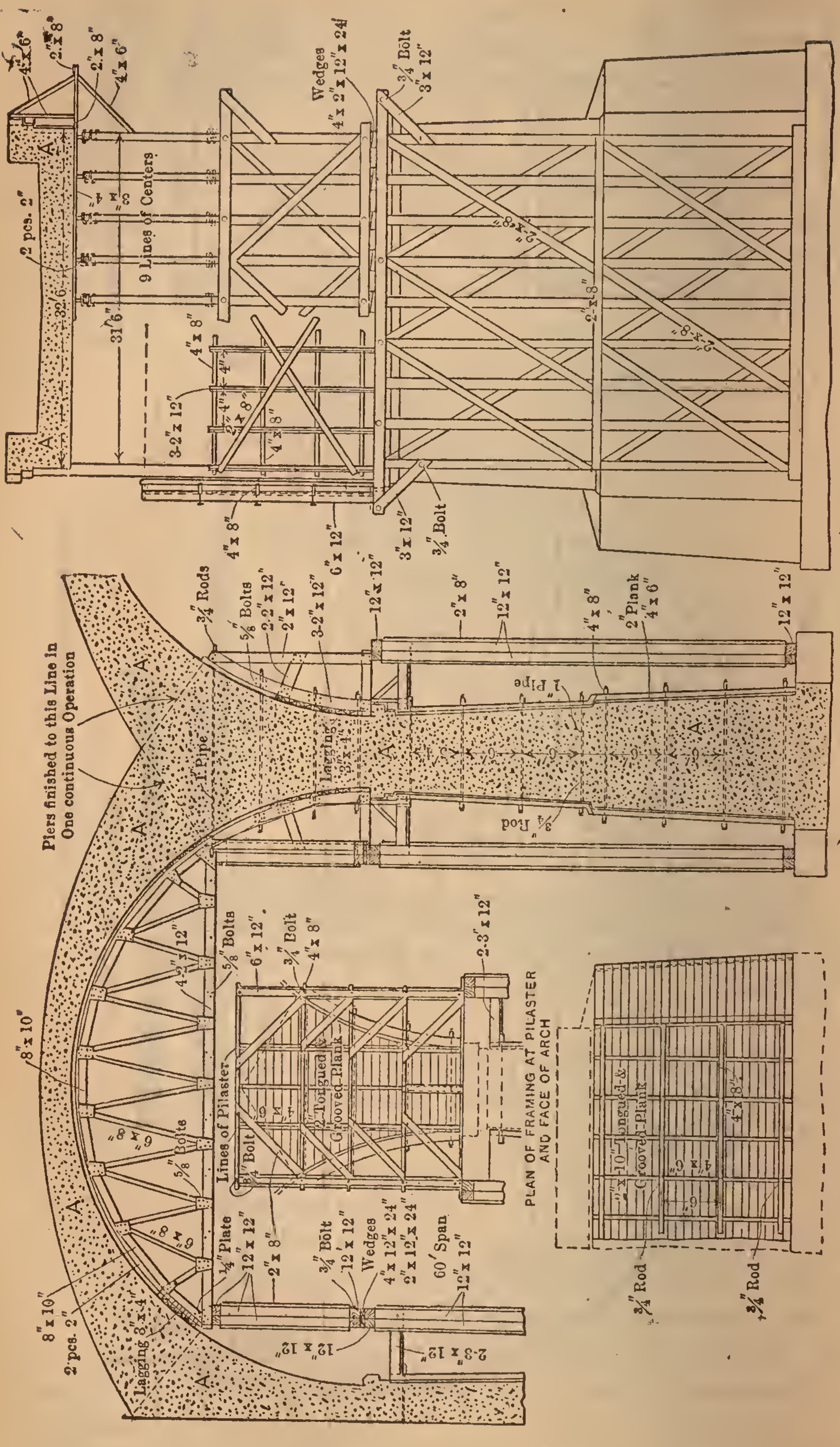


FIG. 24.—Design and Construction of Centering of Pennypack Bridge.

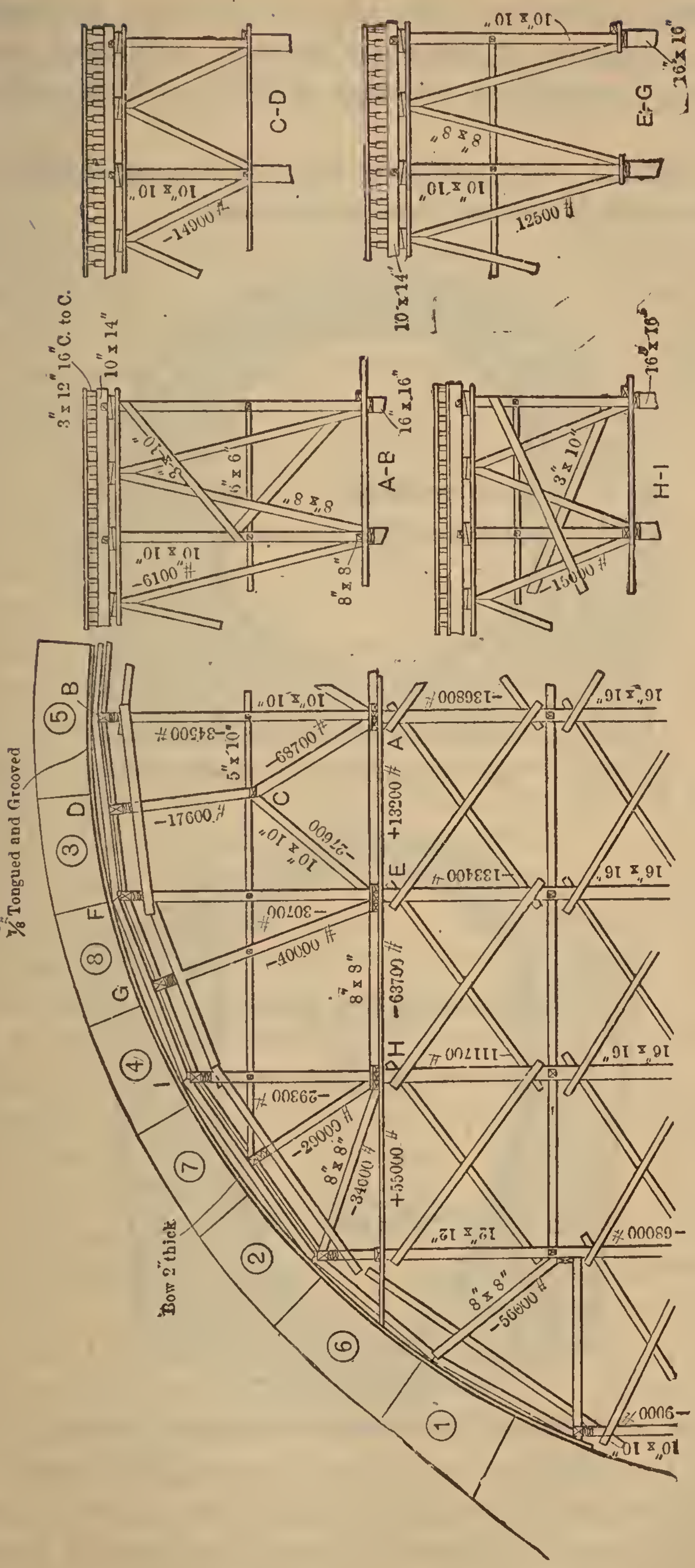


Fig. 25.—Centering used in Constructing Connecticut Avenue Bridge, Washington, D. C.

The centering for large and heavy arches should always be supported with posts of sufficient strength extending down to good bearing foundations, so there will be as little settlement as possible.

Metal Forms.—For various concrete work, especially sewers, collapsible metal forms are now being used.

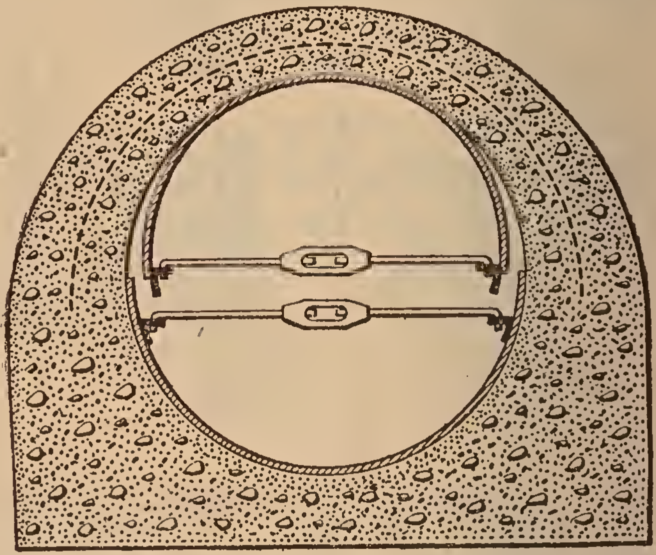


Fig. 26.—"Blaw" Centering for Round Sewer.

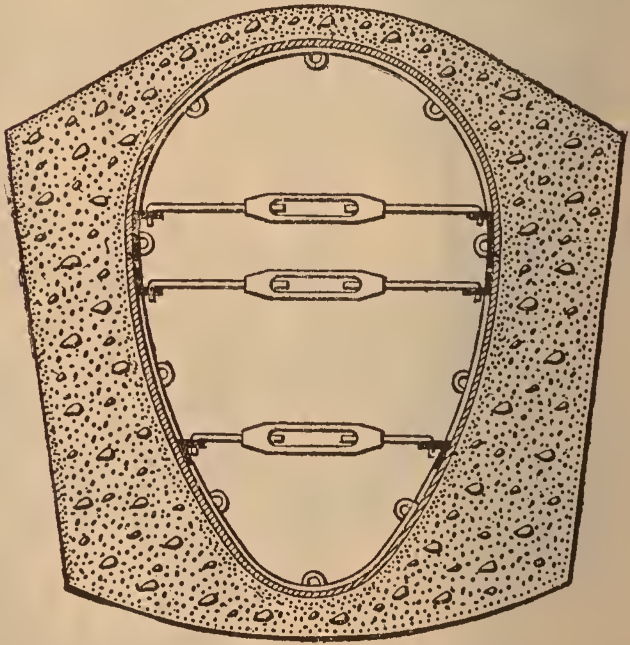


Fig. 27.—"Blaw" Centering for Egg-shaped Sewer.

Figs. 26 and 27 show the "Blaw" collapsible steel sewer centre. The concrete is put in place around the centre as shown, and as soon as hard enough the centering is collapsed, moved along and set up again, thus using the same centering repeatedly on the same piece of work.

Specifications for Forms.—The following specification for the construction of concrete forms is an excerpt from the "Specifications of the Piney Creek Concrete Bridge, Washington, D. C.:"

20. FORMS.—All forms for all classes of concrete shall be closely laid and strongly braced. The contractor shall, before proceeding with the work, submit drawings of the forms to the engineer for his approval. All lagging shall be tongued and grooved, and the studding for all the work shall be dressed or sawed to an even thickness. All forms, except by the consent of the engineer, shall be held in place by means of bolts, so made that the outer 3 ins. of the bolts can be removed after the forms are taken down, and the remaining holes shall be filled with mortar (1–3). If $\frac{7}{8}$-in. lagging is used the studs shall not exceed 18 ins. on centres, and if 2×8-in. studs are used the wales shall not be less than 8×8 ins. These wales on a basis of 2×8-in. studs shall not be further apart than 8 ft., nor shall the bolts which hold them and which have diameters of $\frac{3}{4}$ in. be further apart than 8 ft.

If lagging studs, wales or bolts are proposed by the contractor other than those described hereinbefore, they shall be such as to make a form of equal strength and stiffness to that described.

Washers shall be used under all bolt heads, and nuts and before proceeding with the concrete work forms shall be brought true to line and grade and all bolts shall be taut.

27. CENTRES FOR ARCH.—Complete drawings of the centres with a description of the various materials to be used shall be submitted by the contractor to the engineer, free of cost to the District of Columbia, and no work shall be done on the construction of the said centres until said drawings have been approved in writing by the engineer.

28. GENERAL DESCRIPTION OF CENTRES.—The centres shall be built for the full-width of the bridge (25 ft. between faces of arch rings). The contractor will not be allowed to use centres having trussed spaces greater than 20 ft., but must carry posts down from the bow to suitable foundation. Bows in no case shall exceed 6 ft. 6 ins. on centres. They shall be stiffly sway-braced, both transversely and longitudinally. The foundations for the centres shall be of concrete of the same kind and according to the specifications hereinbefore specified for the permanent work. They shall be of such size as will not permit of a settlement greater than $\frac{1}{4}$ in. under the maximum loads

they are designed to carry. The tendency of the centres to rise at the crown as they are loaded at the haunches must be provided for in the design, or if not the centres must be temporarily loaded at the crown and the load so regulated as to prevent distortion of the arch as the work progresses.

29. Materials.—Merchantable long-leaf pine lumber (in accordance with the specifications adopted by the Southern Lumber and Timber Association, Feb. 14, 1883) shall be used throughout, excepting that sills, corbels, wedges, and all other lumber subjected to side pressure shall be of white oak of the following specifications: White oak must be free from decay, splits, shakes, sawed true and out of wind, and square-edged, full-sized, free from large or loose knots or any other defects which would seriously impair its strength or durability. The wedges shall be of straight-grain oak only. All materials shall be subject to the approval of the engineer. Stresses in all material for the centres will be computed on the basis of one-fifth of the breaking strain of the material used, in accordance with the tables of Messrs. Kidwell and Moore for wooden beams and columns, 1899. In the design of the centre care shall be taken so that the centre will be stiff. The joists, caps and bows shall not have a deflection exceeding $\frac{1}{4}$ in. under the full load of the arch, or the partial load of the arch, the concrete being figured as a liquid having a weight of 150 lbs. per cu. ft.

30. Joints.—No dependence will be placed in nails, except for fastening the lagging, for securing the wedges, and for minor details, and then only upon the approval of the engineer. All joints shall be made with bolts and with straps or gussets of steel or iron, if in the judgment of the engineer they are necessary in the design submitted.

31. Lagging.—The lagging may be made in two thicknesses if the contractor so desires. The top layer to be tongued and grooved lumber not less than $\frac{7}{8}$ in. thick, and the lower layer dressed to a matched top surface when in place. Lagging shall not have a deflection under the full load of the arch or under the partial load exceeding $\frac{1}{8}$ in. The concrete being figured for partial load as a liquid having a weight of 150 lbs. per cu. ft. The lagging shall be kept wet for three weeks after the keying of the arches.

32. Striking Centres.—The crowns of the centres shall be raised above the intended height of the finished arches to allow for settling when the centres are being loaded and when struck.

The centres shall be struck when directed by the engineer, which direction will not be given until the masonry above them has been completed up to the level of the bottom of the coping. Wedges shall have a batter of (one inch in ten), and the pressure per square inch on the same shall not exceed 300 lbs. per sq. in. The grain of same shall run with the batter and their contact faces shall be planed true and smooth for their entire width and length, and if so ordered by the engineer, they shall be lubricated to facilitate the striking of the centres without unnecessary jar. If the contractor wishes to use sand boxes to lower the centres, he shall submit details of the same for the approval of the engineer. The said boxes shall be water-proof and the sand used in the same shall be thoroughly washed to remove all silt and thoroughly dried before using. The centering shall not be paid for directly, but the payment of the same shall be included in the price for the arch concrete, in accordance with the schedule of prices hereinafter to be determined upon.

Laying Out Work.—TO DRAW OR LAY OUT A REVERSE CURVE.—Draw the two lines that are to be connected by the

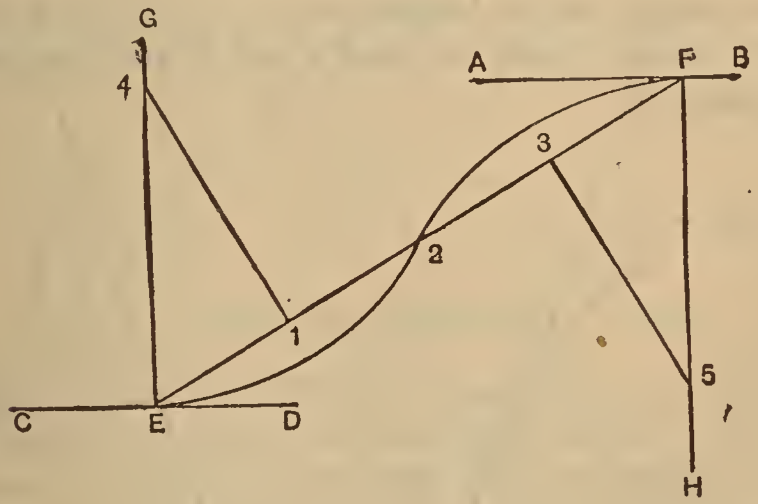


FIG. 28.—Reverse Curve.

reverse curve, as *AB* and *CD*, Fig. 28. From the points on these lines that it is desired to connect with the reverse curve, draw a diagonal line as *EF*, and divide it into four equal parts by points 1, 2, and 3.

From *E* draw a perpendicular line at right angles to *CD*, as *EG*, and from point 1, draw a line at right angles to *EF* until it strikes *EG* and establishes point 4. With this point as centre and 4*E* as radius, strike the half of the curve from *E* to 2. Repeat the operation for the other half of the

curve as shown. This curve is much used in laying out walks, etc.

This curve can also be made by using two arcs of different radii, as shown by Fig. 29. Divide the diagonal EF into two

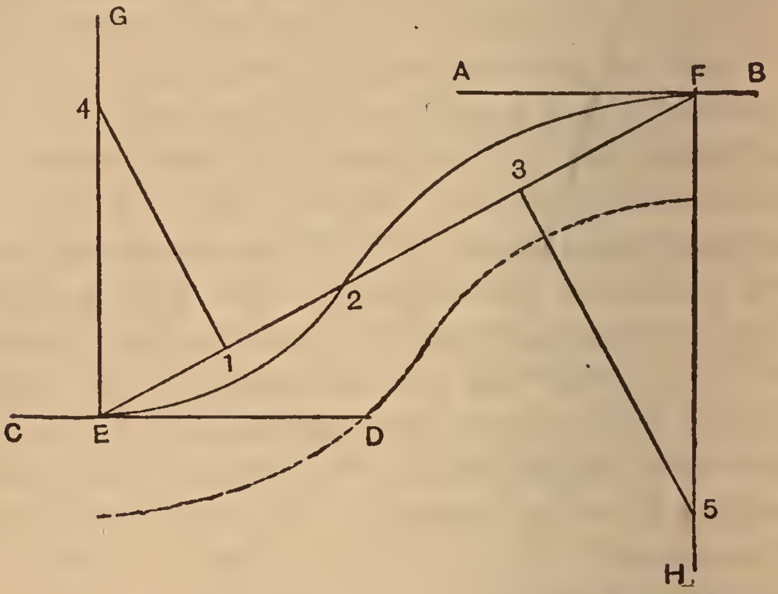


Fig. 29.—Reverse Curve composed of Arcs of Different Radii.

spaces, according to the desired curve as $E2$ and $2F$. Find the centre of each space, as point 1 and 3, and proceed as previously explained.

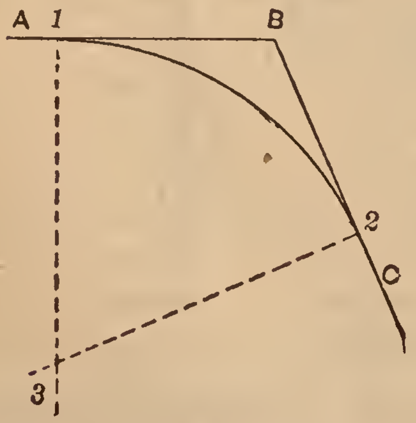


Fig. 30.—Laying Out an Obtuse Round Corner.

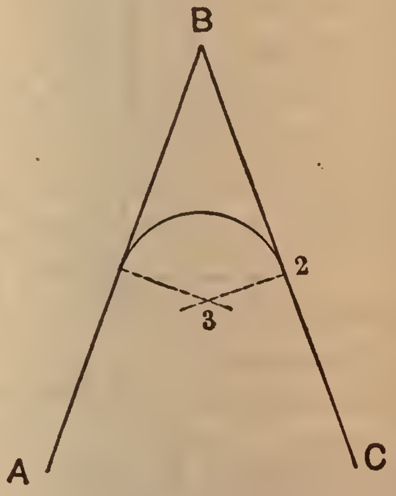


Fig. 31.—Laying Out an Acute Round Corner.

The reverse curve can be used only when the diagonal EB is at an angle of 45 degrees or less.

The dotted line shows the other side of the walk, it being laid out by using the same centres as above, but radii to suit the width of the walk.

To Lay Out the Curve for an Angle of Curb or Sidewalk.—On the lines of the curb or walk, as AB and BC, Figs. 30 and 31, measure back each way from B the desired distance, as points 1 and 2, from these points draw lines at right angles to AB and BC to intersect at 3. This intersection is the centre and 3 1 the radius to draw the curve as shown.

To Lay Out a Curve Corner for Curb or Sidewalk when the Radius is Given.—Draw lines representing the line of the curb or walk, as AB and CD, Fig. 32. Then at a distance equal to the radius of the desired circle draw lines parallel

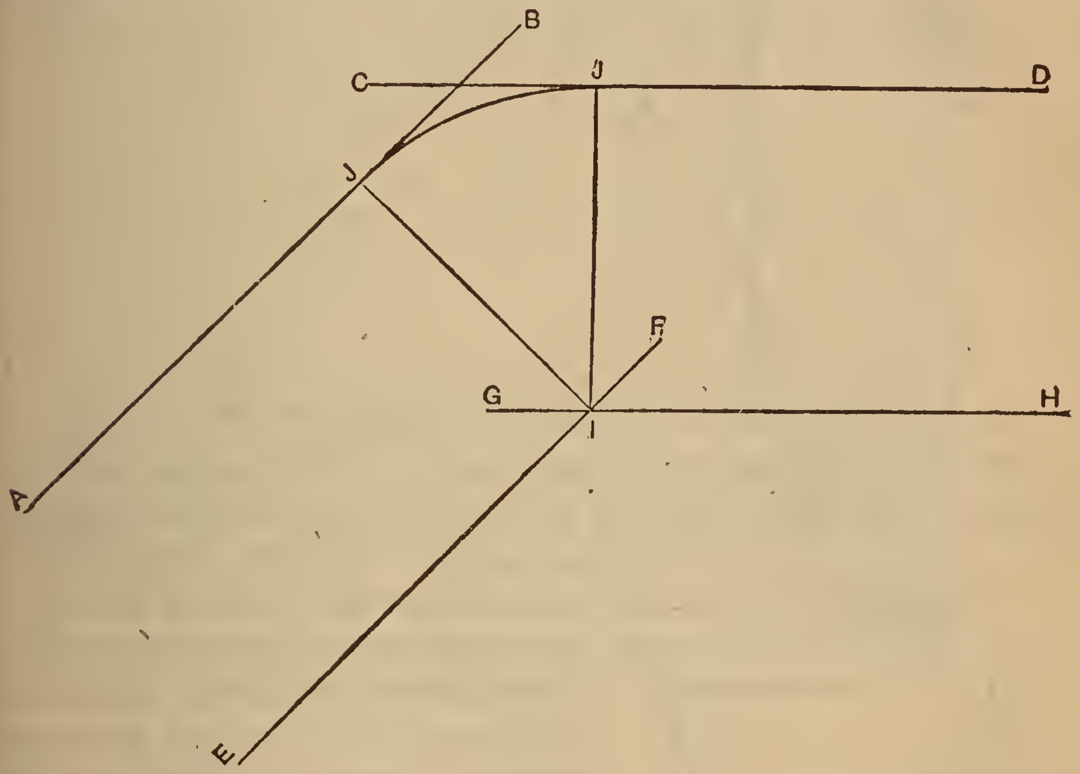


Fig. 32.—Laying Out Corner Curve of Sidewalk.

to AB and CD, as EF and GH, intersecting at I, which is the centre, and IJ the radius to draw the curve. The point of intersection of the circle and straight line is found by drawing lines from I at right angles to EF and GH to strike the lines AB and CD, as IJ, J being the intersection of the circle and straight line.

To Lay Out the Intersection of Two Walks of Different Widths.—Lay out the lines of the two walks as ABC and DEF, Fig. 33, and from the point on the narrow walk where the intersection of the straight and circle is desired, as G, draw GH parallel to BC.

On GH make GI equal to GB, I being the centre and IG the radius for the outer curve. Now on GH make JK equal

to JE and K is the centre and KJ the radius for the inner curve as shown.

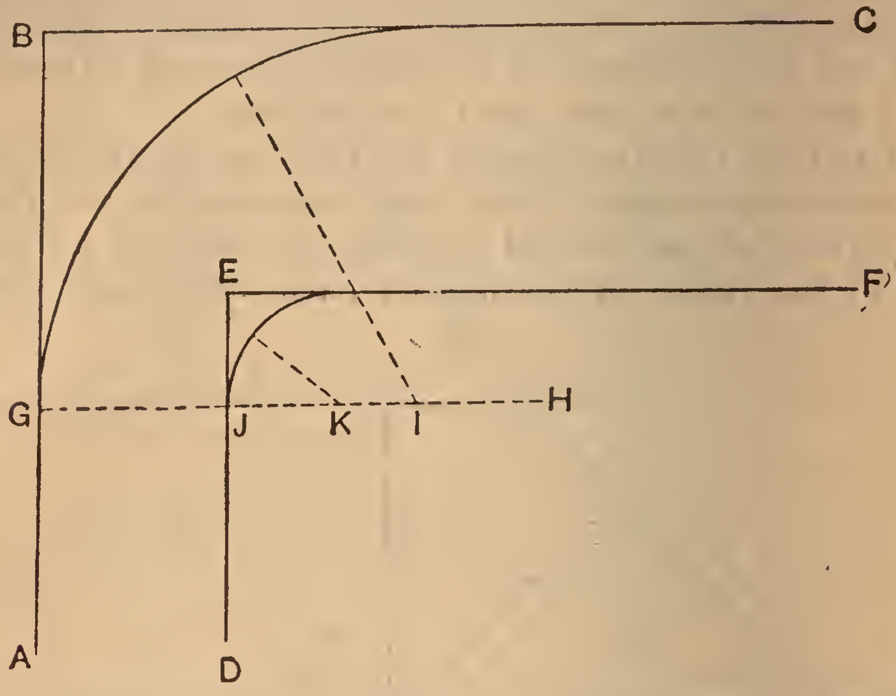


Fig. 33.—Connecting Two Sidewalks of Different Widths at a Corner.

To Find the Bevel of Skew-backs.—To find the bevel or slope of the skew-back for Jack arches, lay out the opening, as $ABCD$, Fig. 34. With AB representing the width of the opening, take AB as radius and A and B as centres, and draw the curves as shown, thus finding the intersecting point E. Now draw EG and EF through points A and B, thus giving the bevels as shown.

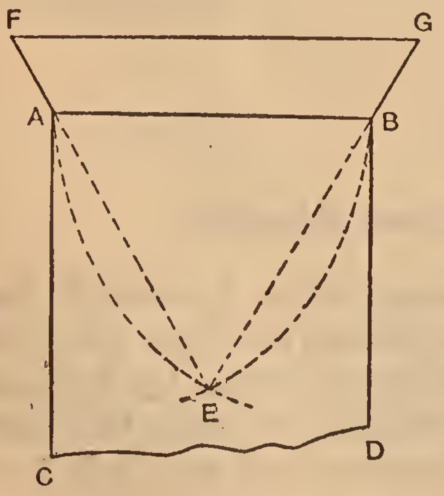


Fig. 34.—Bevel of Skew-back.

To Obtain Cuts or Angles on a Square.—Fig. 35 shows a diagram to obtain cuts or degrees on a square; for instance, if angle of 30° is desired, 7 and 12 on the square will give it.

To Mitre a Circle and Straight Moulding.—Draw a full-size plan of the two mouldings, as shown in Fig. 36; draw abc, as shown, in the centre of the space between the two outside lines; connect d and b and b and e; bisect db and be and draw lines at right angles to them to meet at f; then fd is the radius of the mitre joint.

To Lay Out a Rake Moulding to Join the Moulding on the Square Set on a Plumb Facia.—Mark out the square moulding, as *a*, with *bc* as the facia, Fig. 37; then draw lines

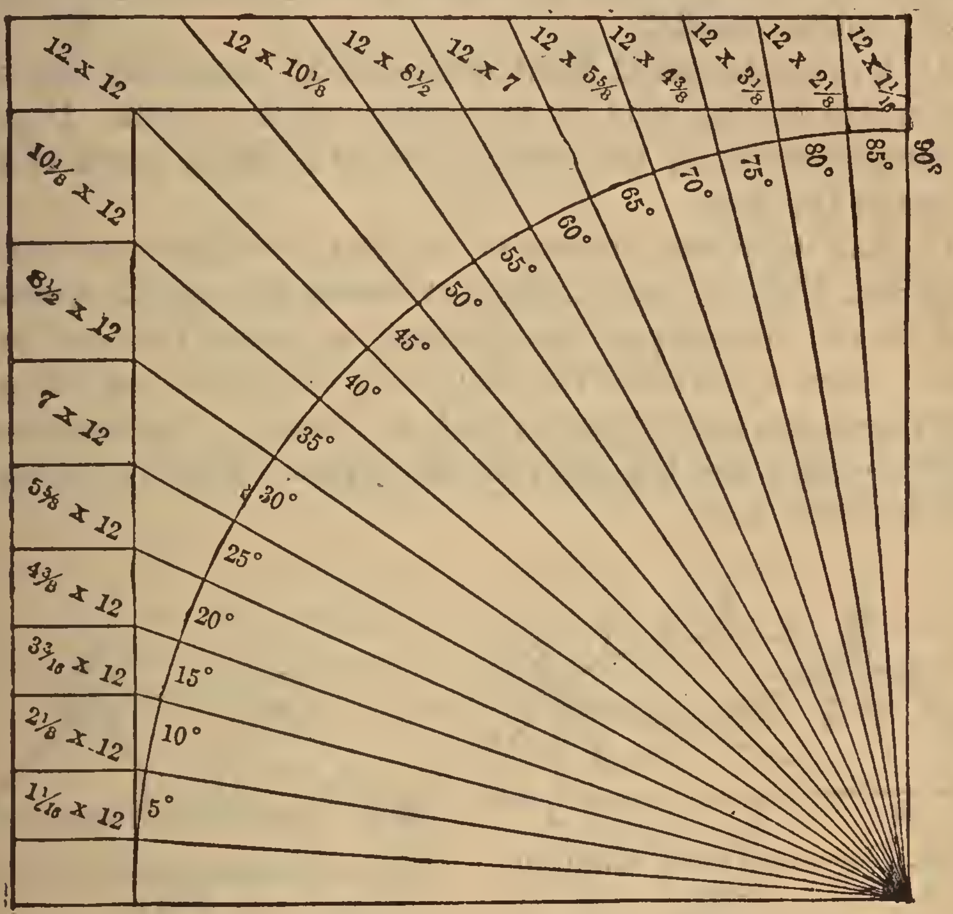


Fig. 35.—Cuts or Degrees on a Square.

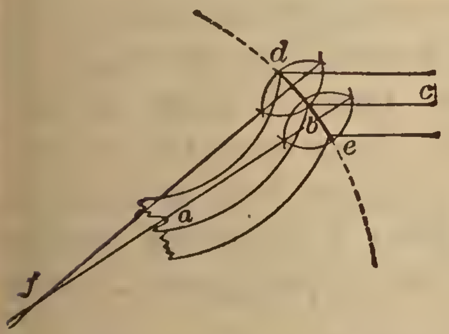


Fig. 36.—Intersecting Mouldings.

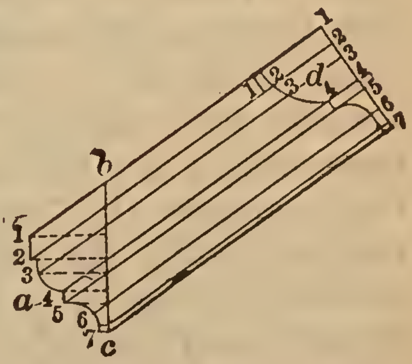


Fig. 37.—Joining Level and Rake Moulding.

at right angles to the facia, joining all the breaks in the moulding, as 1, 2, 3, 4, etc.; then draw lines from these points on the moulding with the rake of the roof, as 1 1, 2 2, 3 3, etc., and draw a line at right angles to these, as 1 7 at *d*; make line 1 1 at *d* the same length as 1 1 at *a*, and 2 2 at *d* same as

at *a*, etc.; then join these points as shown, thus giving the profile of the rake moulding.

All plumb lines radiate from the centre of the earth, showing that if it were possible to make walls perfectly plumb they would not be parallel.

All level lines are at right angles to an imaginary line from the centre of the level to the centre of the earth. If a line is drawn parallel to the earth's surface it has a curve of eight inches to the mile.

To Lay Out the Joints in an Elliptic Arch.—Draw the arch *abc*, Fig. 38, and divide the curve into equal spaces, as 1, 2, 3, etc., making as many spaces as joints required in the arch; draw lines from the foci *dd* to the points on the curve and bisect the angle thus formed, as shown. The lines bisecting this angle are the lines of the joints. Repeat the operation for each joint.

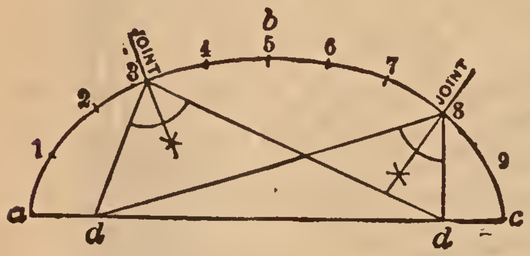


Fig. 38.—Joints in an Elliptical Arch.

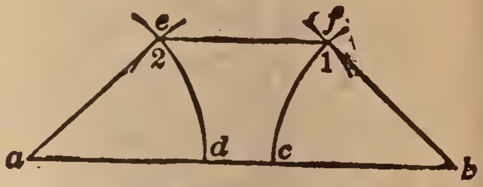


Fig. 39 —Laying out Octagon Bay.

To Lay Off an Octagon Bay when the Length of One Side is Given.—First draw a line to represent the side of the house, as *ab*, Fig. 39; then with the trammel set the length of the side, place the foot at *a* and find point *d*; make the distance from *d* to *c* five-twelfths of *ad*; then with the foot of the compasses at *c*, find point *b*; with the foot at *b*, strike the arc *cf*; with the foot at *d*, find point 1; with the foot at *a*, strike the arc *de*; with the foot at *c*, find point 2; then connect *ae*, *ef*, and *fb*.

To Lay Out a Hexagon Bay Window when the Length of One Side is Given.—Draw the line *ac* as side of the house, Fig. 40; then, with *a* as centre and the given side as radius, strike arc *db*; then, with *b* as centre, find point *c*; then, with *c* as centre, strike arc *eb*; now with *b* as centre, strike semicircle *adec*; now connect *ad*, *de*, and *ec*.

To find the side of an octagon bay when the length on the house is given: Divide the distance on the house by 2⁵⁄₁₂, and the answer will be the length of the side.

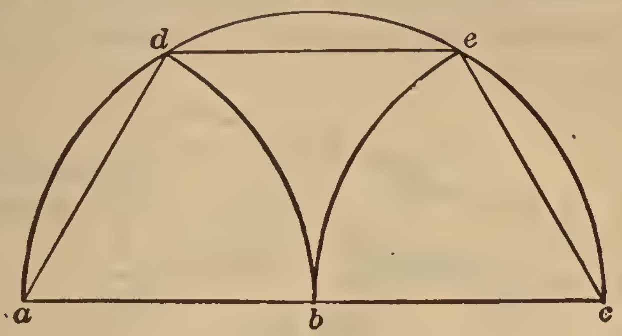


FIG. 40,—Laying out a Hexagon Bay.

To find the distance on the house when the side is given: Multiply the side by 2⁵⁄₁₂, and the answer will be the diameter of the octagon.

TO STRIKE AN OGEE FOR A BRACKET.—Lay off the width and length of the bracket, as *ac* and *ab*, Fig. 41; then draw the line shown at the back of bracket an inch, or more if desired, from the edge of board; then draw the diagonal *cd*; then divide

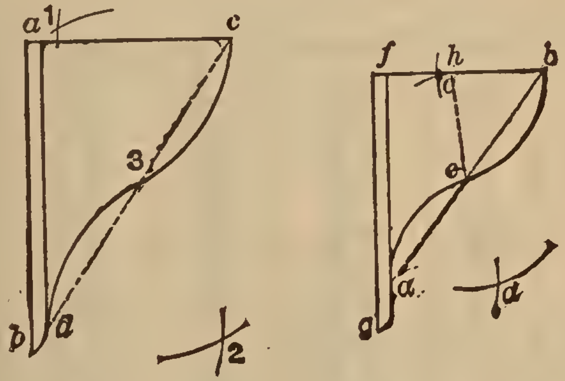


FIG. 41. FIG. 42.
Ogee Brackets.

cd into two equal parts at 3; then, with 3 as centre and 3*c* as radius, strike arc at 1; then, with *c* as centre and same radius, strike arc intersecting at 1; then, with 1 as centre, strike arc *c*3; then, with 3*d* as centre, strike arcs intersecting at 2; then, with 2 as centre, strike arc 3*d*.

ANOTHER WAY TO LAY OFF A BRACKET.—With *fg* as edge of board and *fb* as end or top of bracket, Fig. 42, draw the dotted line, as shown; then draw the diagonal *ab* and divide it into two equal parts at *e*; then, with *eb* as centres and *eh* as radius, strike arcs intersecting at *c*; then, with same radius and *c* as centre, strike arc *be*; then, with same radius and *ae* as

centres, strike arcs intersecting at *d*; then with *d* as centre, strike arc *ea*.

To Lay Out Angles.—Th following tables of angles is to be used in connection with a two-foot rule or a pair of compasses to lay out any angle desired, as shown by Fig. 43.

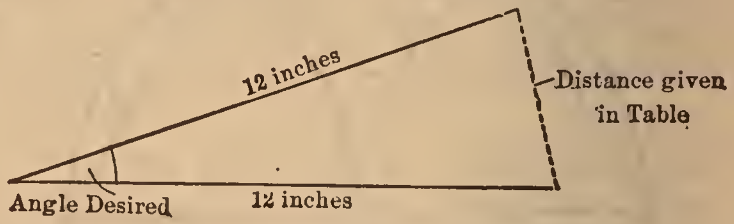


FIG. 43.

Example.—To lay out an angle of 15° take the two 12-inch arms of a two-foot rule and open them 3.13 inches, when the two arms will give the desired angle.

ANGLES AND DISTANCES.

ANGLES AND DISTANCES CORRESPONDING TO THE OPENING OF THE TWO-FOOT RULE.

Angle.	Distance.	Angle.	Distance.	Angle.	Distance.	Angle.	Distance.
Deg.	Ins.	Deg.	Ins.	Deg.	Ins.	Deg.	Ins.
1	.2	24	4.99	47	9.57	69	13.59
2	.42	25	5.19	48	9.76	70	13.77
3	.63	26	5.4	49	9.95	71	13.94
4	.84	27	5.6	50	10.14	72	14.11
5	1.05	28	5.81	51	10.33	73	14.28
6	1.26	29	6.01	52	10.52	74	14.44
7	1.47	30	6.21	53	10.71	75	14.61
8	1.67	31	6.41	54	10.9	76	14.78
9	1.88	32	6.62	55	11.08	77	14.94
10	2.09	33	6.82	56	11.27	78	15.11
11	2.3	34	7.02	57	11.45	79	15.27
12	2.51	35	7.22	58	11.64	80	15.43
13	2.72	36	7.42	59	11.82	81	15.59
14	2.92	37	7.61	60	12	82	15.75
15	3.13	38	7.81	61	12.18	83	15.9
16	3.34	39	8.01	62	12.36	84	16.06
17	3.55	40	8.2	63	12.54	85	16.21
18	3.75	41	8.4	64	12.72	86	16.37
19	3.96	42	8.6	65	12.9	87	16.52
20	4.17	43	8.8	66	13.07	88	16.67
21	4.37	44	8.99	67	13.25	89	16.82
22	4.58	45	9.18	68	13.42	90	16.97
23	4.78	46	9.38				

TO FIND MITRES ON THE STEEL SQUARE.—12×12 equals square mitre; 7×4 equals triangle mitre; $13\frac{3}{4}$×10 equals pentagon mitre; 4×7 equals hexagon mitre; $12\frac{1}{2}$×6 equals

heptagon mitre; 7×17 equals octagon mitre; $22\frac{1}{2} \times 9$ equals nonagon mitre; $9\frac{1}{2} \times 3$ equals decagon mitre.

To Lay Out Arches.—LANCET GOTHIC ARCH.—A lancet Gothic arch is one whose radius is greater than its width, as shown in Fig. 44.

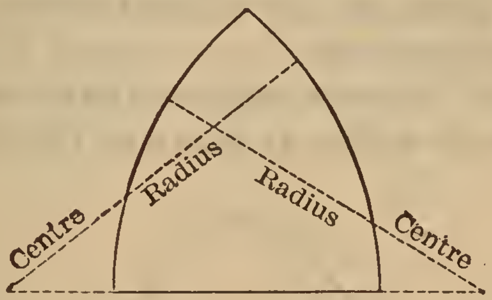


FIG. 44.—Lancet Gothic Arch.

TO DRAW THE GOTHIC ELLIPTICAL ARCH.—Divide the span *ab* into three equal parts at *c* and *d*, Fig. 45; with *bc* as radius

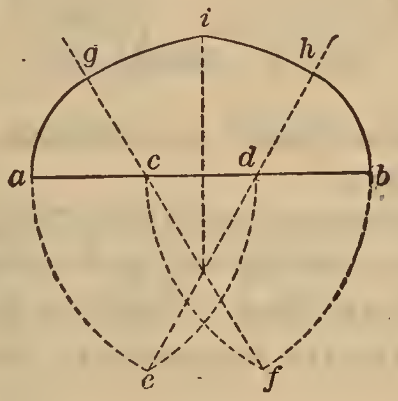


FIG. 45—Gothic Elliptical Arch.

and *a*, *c*, *d*, *b* as centres, draw the arcs, as shown, finding points *e* and *f*; now, from *e* and *f* draw lines through *c* and *d*, as shown; with *c* and *d* as centres and *ac* as radius draw arcs *ag* and *hb*,

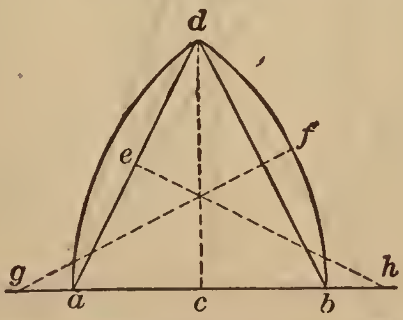


FIG. 46.—Lancet Gothic Arch.

and with *e* and *f* as centres and *eh* as radius draw arcs *gi* and *ih*, completing the curve of the arch.

TO DRAW THE LANCET GOTHIC ARCH WHEN THE SPAN AND RISE ARE GIVEN.—On the base line, Fig. 46, mark the span *ab* and from the centre draw the rise *cd*; now connect *ad* and *db*, and from the centre of these lines draw a line at right angles to strike the base line, as *gf* and *eh*; now *g* is the centre and *gb* the radius to draw the arc *db*, and *h* the centre and same radius to draw the arc *ad*.

GOTHIC ARCH.—The most common Gothic arch is one whose radius is equal to its width, as shown in Fig. 47.

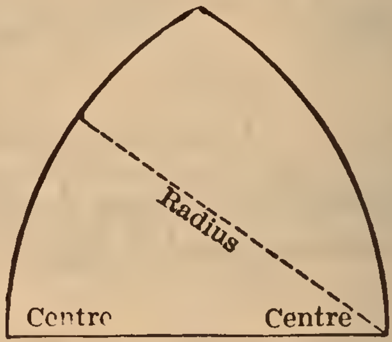


FIG. 47.—Gothic Arch.

All Gothic arches are easily struck from the centre, usually shown on the drawings.

TO DRAW A FLAT-POINTED ARCH TO A GIVEN WIDTH AND RISE —Draw the width, as *AB*, Fig. 48, and the height, as *OC*, while *CD* is a line tangent to the upper circle; now draw *C*3 at right angles to *DC*, and from *A* draw the perpendicular *AD*; now find point *I*,

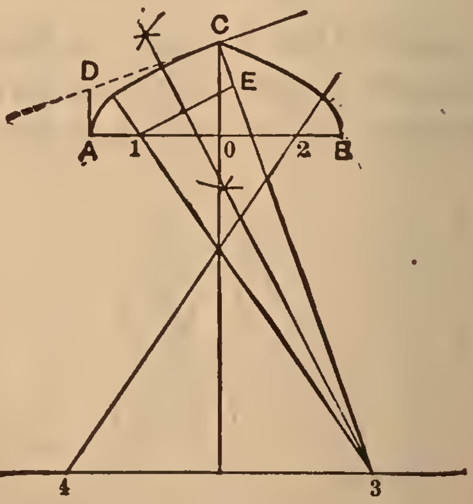


FIG. 48.—Flat-pointed Arch.

making *AI* equal to *AD*; now find point *E*, making *CE* equal to *AD*, and connect *I* and *E*; now bisect the line *EI*, as shown,

and draw a line to meet $C3$; now from 3 draw a line through point I as $3D$, and I and 3 will be the centres to strike the arch; then transfer the points across to 2 and 4 for the centres for the other half.

Drop Arch.—A drop arch is one whose radius is less than its width, as shown in Fig. 49.

Another form of drop arch is shown in Fig. 50.

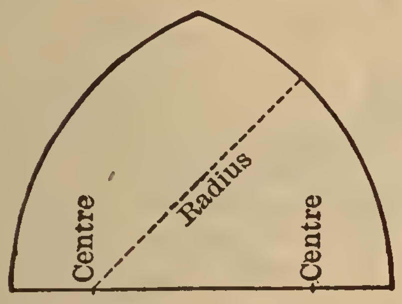


Fig. 49.—Drop Arch.

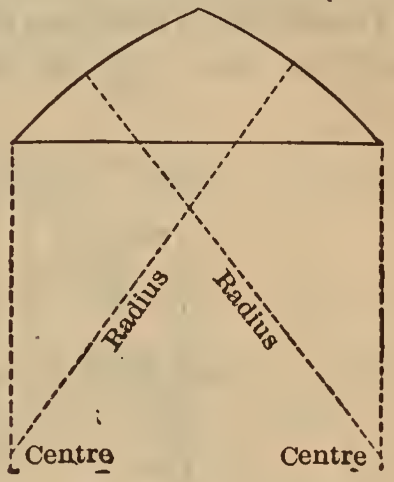


Fig. 50.—Drop Arch.

Three-centre Arch.—With ab as width of arch and e as centre, Fig. 51, take ea as radius and strike semicircle ab; then, with a as centre and ab as radius, strike arc bc; then,

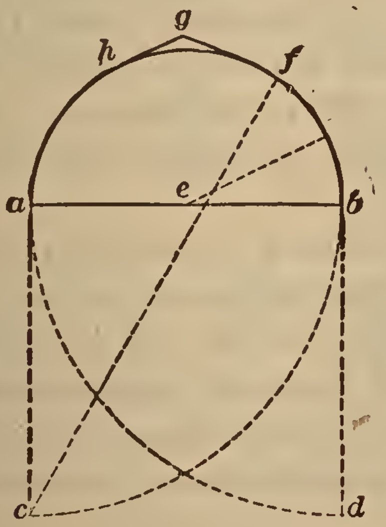


Fig. 51.—Three-centre Arch.

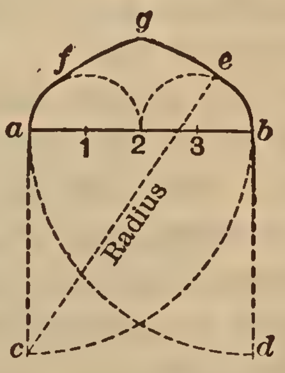


Fig. 52.—Four-centre Arch.

with b as centre and same radius, strike arc ad; then, with c as centre and cf as radius, strike arc gf; then, with d as centre and same radius, strike arc gh, thus completing the arch.

FOUR-CENTRE ARCH.—To strike a four-centre arch divide the width into four equal spaces, as 1, 2, 3, Fig. 52; then, with 1 as centre and 1*a* as radius, strike semicircle *a*2; then, with 3 as centre and same radius, strike semicircle 2*b*; then, with *ab* as radius and *a* as centre, strike arc *bc*; then, with same radius and *b* as centre, strike arc *ad*; then, with *c* as centre and *ce* as radius, strike arc *ge*; then, with same radius and *d* as centre, strike arc *fg*, completing the arch.

TO DRAW THE TUDOR OR GOTHIC ARCH.—Let *ab* be the span and *cd* the rise, Fig. 53; with *ab* as radius and *c* as centre

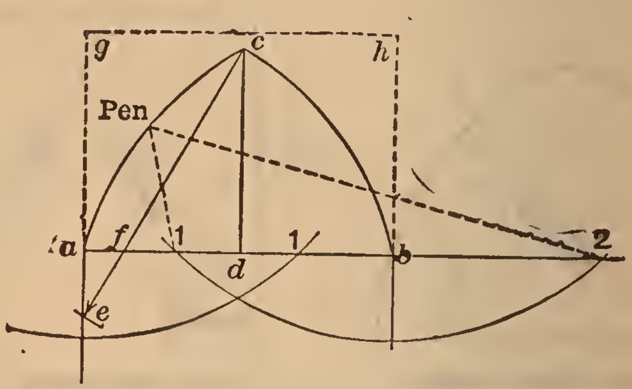


FIG. 53.—Tudor Arch.

draw an arc through the perpendicular at *e*, connect *c* and *e*, make *ag* and *bh* equal to *cf*; now, with *ab* as radius and *g* and *h* as centres, find points 1 1 and 2 2 on the base line; drive a nail in each of these points to attach a string; fasten the string at 2 and carry it around the pencil at *c* and make fast at point 1 on the opposite side; now draw the pencil from *c* to *a*, keeping the string tight, and it will describe the arch; then reverse the string for other side.

AT POINT *c* ON THE LINE *ab* TO DRAW TWO ARCS OF CIRCLES TANGENT TO *ab* AND THE TWO PARALLELS *ah* AND *be* FORMING AN ARCH.—Make *ad*, Fig. 54, equal to *ac* and *be* equal to *bc*; draw *cf* at right angles to *ab* and *dg* at right angles to *ah*; with *g* as centre and radius *gd* draw the arc *dc*; draw *ef* at right angles to *be*; with *f* a centre and *fc* as radius draw the arc *ce*, completing the arch.

TO SPACE THE KERFING OF MOULDINGS, ETC.—Strike a circle of the same dimensions as that which it is desired to spring the moulding around; take a piece of the moulding and make a kerf in it and place the moulding across the circle as shown by Fig. 55, with the kerf at the centre; now hold that part

of the moulding marked *A* solid and bend the part marked *B* until the kerf or saw cut comes together. The distance the piece

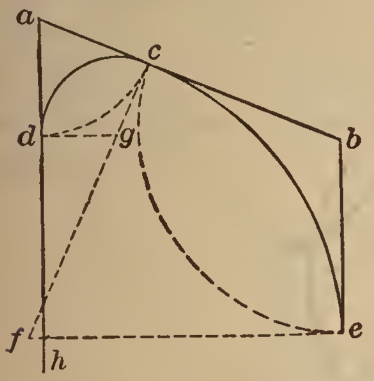


FIG. 54.—Arch of Two Arcs of Circles.

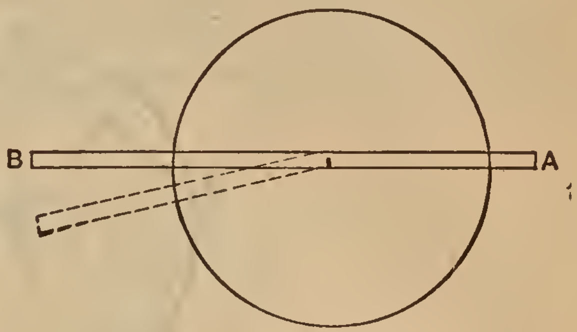


FIG. 55.—Kerfing of Moulding.

of moulding *B* has moved on the circle will be the distance apart to space the kerfs.

TO LAY OUT AN ARCH OR CURVE SIMILAR TO AN ELLIPSE, BUT WHOSE AXES DO NOT STAND AT RIGHT ANGLES.—Draw a parallelogram whose sides equal the axis, as *A*, *B*, *C*, and *D*, Fig. 56; now draw the two centre lines *EF* and *GH*;

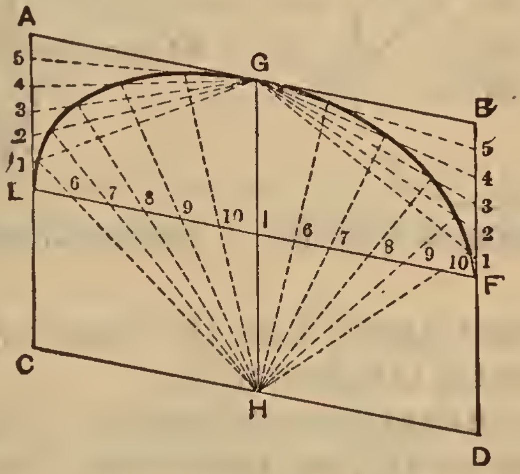


FIG. 56.—Deformed Ellipse.

divide *AE* and *BF* into any number of equal parts, as 1, 2, 3, etc.; then divide *E*1 and 1*F* into the same number of parts and draw lines radiating from *G* to points 1, 2, 3, etc.; then draw lines radiating from *H* through points 6, 7, 8, etc., to strike the lines radiating from *G*, and through these intersections draw the curve as shown.

WHEN ANY THREE POINTS ARE GIVEN, TO DRAW A CIRCLE WHOSE CIRCUMFERENCE SHALL STRIKE EACH OF THE THREE POINTS.—With *a*, *b*, and *c* as the points, Fig. 57, join *a* and *b*

and *a* and *c* together, and draw lines at right angles from the centre of *ab* and *ac*. bisecting at *d*, which is the centre of the circle, and *da* the radius.

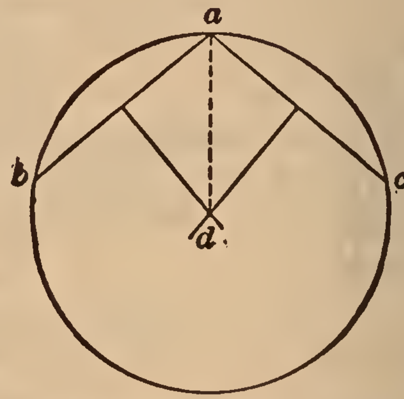


FIG. 57.—To Draw Circle through Three Points.

TO FIND THE CENTRE OF A CIRCLE.—Take any three points on the circumference and join them, as *a*, *b*, *c*, Fig. 58; then

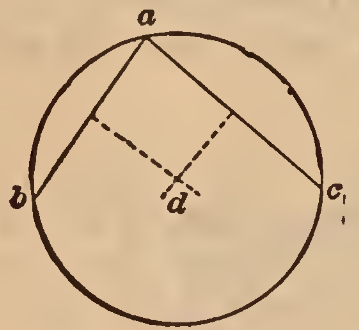


FIG. 58.—Finding Centre of Circle.

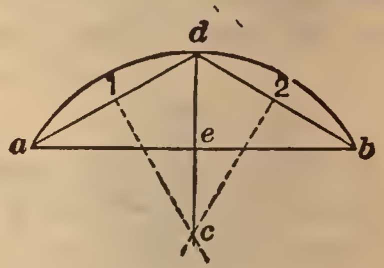


FIG. 59.—Diameter of Arc.

draw lines at right angles from the centre of *ab* and *ac* and the bisecting point *d* is the centre.

TO FIND THE DIAMETER OR RADIUS OF A CIRCLE WHEN THE CHORD AND RISE OF AN ARC ARE GIVEN.—Draw the chord as

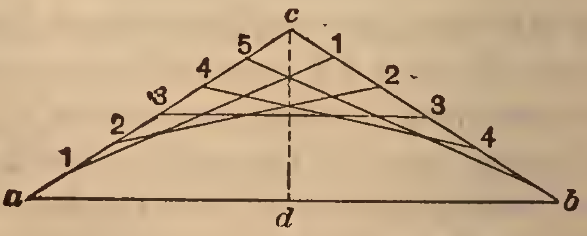


FIG. 60.—To Draw an Arc.

ab, then the rise *de*, Fig. 59; then connect *ad* and *db*; then draw lines 1*c* and 2*c* at right angles, and from the centre of

ad and *db*, until they interesct at *c*, which is the centre and *cd* the radius.

To Draw an Arc by Intersecting Lines when the Chord and Rise are Given.—Draw the chord as *ab*, Fig. 60; then draw *cd* equal to twice the rise, divide *ac* and *cb* into the same number of equal spaces and draw the lines as shown.

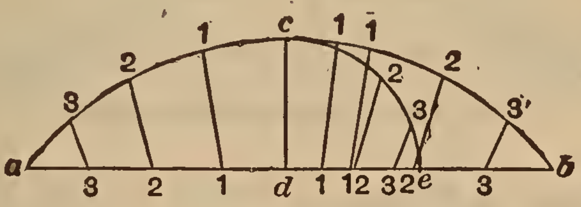


Fig. 61.—**To Draw an Arc.**

To Draw an Arc by Bending a Lath or Strip.—Let *ab* be the span and *cd* the rise, Fig. 61, with *cd* as radius and *d* as centre, draw the quarter-circle *ce*; now divide *ce* and *ed* into the same number of equal parts, as 1, 2, 3, etc.; now divide *db* and *da* into as many equal parts as *de*; now connect 1, 2, 3 on the quarter-circle and 1, 2, 3 on *de*, as shown; now draw lines from the points on *ad* and *db*. at the same angle and equal in length to the ones on the quarter-circle, as 1 1, 2 2, etc.; drive nails in these points and bend the strips around.

When the Span and Rise of an Arc are Given, to Draw the Curve.—Draw the span *ab* and rise *c*, Fig. 62; then, with

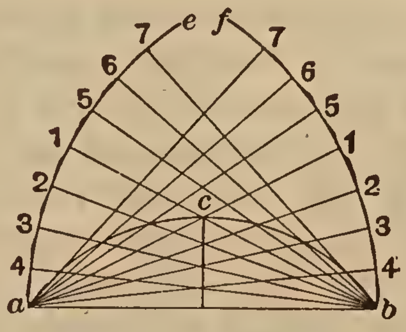


Fig. 62.—To Draw Curve of Arc.

a and *b* as centres and *ab* as radius, draw arcs *ae* and *bf*; now draw lines from *a* and *b* through *c* until they strike *ae* and *bf*, as *a*1 and *b*1; divide *a*1 on *ae* and *b*1 on *bf* into any number of equal spaces, as 1, 2, 3, etc.; make 5, 6, 7 equally distant

and draw the lines as shown; draw the curve through the intersections as shown.

WHEN THE CHORD AND RISE OF AN ARC ARE GIVEN, TO DRAW THE ARC.—Take two strips and joint the edges

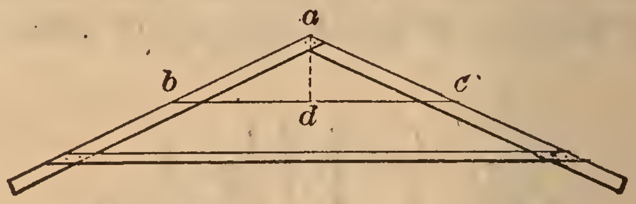


FIG. 63.—Frame to Strike Arc.

straight and make a frame, as shown in Fig. 63; *bc* is the chord and *ad* the rise of the arc. Drive a nail in the floor or drawing-board on the outside edge of the frame at *b* and

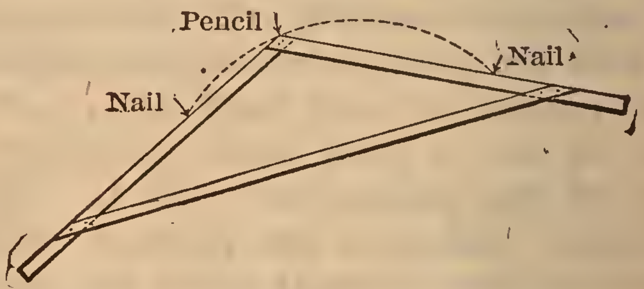


FIG. 64.—Use of Frame.

another one at *c*; then place the pencil at the point of the frame, *a*, and slide the frame around, keeping it tight against the nails, when the pencil will describe the curve, as shown in Fig. 64.

WHEN THE CHORD AND RISE OF AN ARC ARE GIVEN, TO FIND THE RADIUS.—Square one half the chord, divide this product by the rise and to this answer add the rise and divide by 2; the answer is the radius. In Fig. 65, one half the chord is 4, which squared equals 16, which divided by the rise equals $5\frac{1}{3}$, to which add the rise, equals $8\frac{1}{3}$, which divided by 2 equals $4\frac{1}{6}$, the radius.

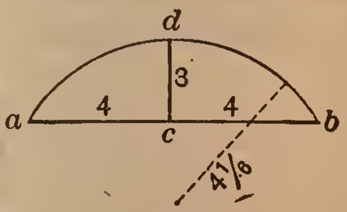


FIG. 65.

LAYING OUT MANSARD AND GAMBREL ROOFS.—To proportion a mansard or gambrel roof, draw a half-circle to a scale, using the width of the building as the diameter, then draw the two slopes of the roof so that they intersect on the circle, as shown by Fig. 66.

Laying Out Circle Heads in Circle Walls.—This can be done with lines and circles, but the quickest way for the work-

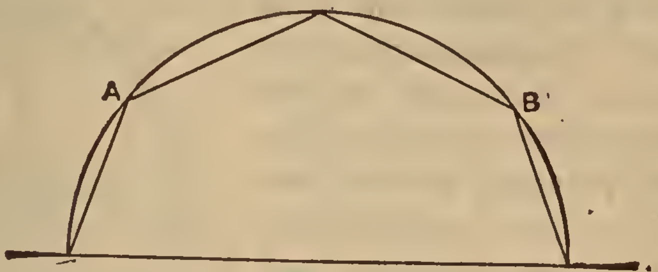


Fig. 66.—Mansard or Gambrel Roof.

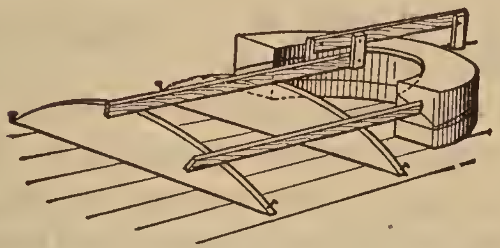


Fig. 67.—Working Circle on Circle-heads.

man is to cut out the head-piece to the desired circle for the frame; then make two templates equal to the circle of the wall and tack them on the drawing-board or floor, as shown by Fig. 67; now with a couple of straight-edges and pencil mark out the circle of the wall by sliding the strips over the templates.

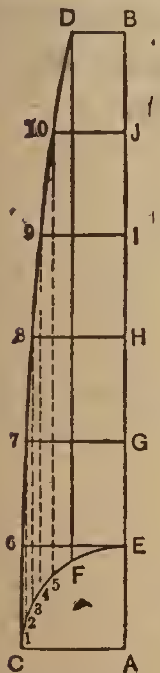


Fig. 68.—Entasis of Columns.

To Lay Out Entasis of Columns, etc.—Draw length of column, as AB, Fig. 68, then AC, the radius of the column at the bottom, and DB, the radius of the column at the top; now describe the quarter-circle CE, and let fall the perpendicular DF. Divide the length of the column into spaces equal to the bottom radius, spacing from E, as G, H, I, and J; divide the arc CF into the same number of equal spaces; now draw lines from the points on the centre line and at right angles to it, as $E6$, $G7$, etc., and draw perpendicular lines from points 1, 2, etc., on the arc to strike the lines from the centre line, as shown at 6, 7, 8, etc., and through these points draw the curve. Fig. 68 is drawn with considerable swell, so that the lines can be seen more plainly.

To Draw a Regular Polygon of any Number of Sides when the Length of One Side is Given.—Take the length of the side for a base, as *ab*, Fig. 69; then with *ab* as radius and *a* as centre draw the semicircle, *db*; then divide the semicircle into as many equal parts as there are sides to the polygon, in this case 7; then, as we have one side, *ab*, we skip the first division and connect *a* and 2; then from the centre of *a*2 and *ab* draw lines at right angles until they meet at *c*, which is the centre of the polygon. Then, with *c* as centre and *ca* as radius, draw the circle; then draw lines from *a* through points 3, 4, 5, and 6, striking the circle at *h*, *g*, *f*, and *e*; now connect 2*h*, *hg*, *gf*, *fe*, and *eb*.

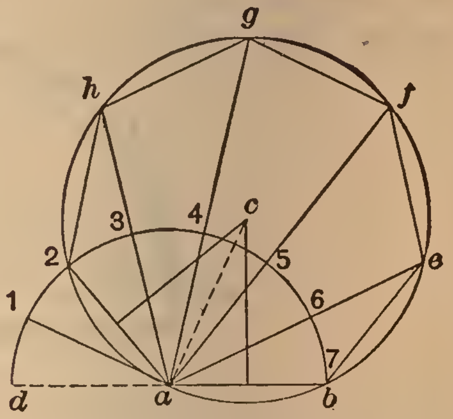


Fig. 69.—To Draw Polygons.

When the Two Axes are Given, to Draw a Curve Approximating an Ellipse.—With *cd* as the major axis and *ag* the minor axis, Fig. 70, draw lines connecting *ad* and *ac*; then, with *b* as centre and *ba* as radius, draw the semicircle, finding points *e* and *f*, from which points draw lines at right angles to *ad* and *ac*, intersecting at *g*; then, with *ga* as radius and *g* as centre, strike arc 1 2; then, with *i* as centre and *i*2 as radius, strike arc 2*d* and repeat same for other side.

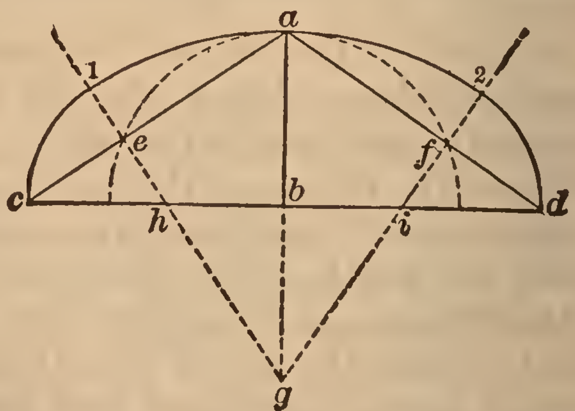


Fig. 70.—Curve Approximating an Ellipse.

To Draw an Ellipse with a String.—Draw the long diameter, Fig. 71, as *ab*; then half the short diameter, as *cd*; then with *c* as centre and *ad* as radius, describe arcs bisecting *ab* at 1 and 2, at which points drive a nail to fasten the string;

then fasten the string at 1 and stretch to c, at which point place a pencil inside the string and carry the string to 2 and make fast; then keep the string tight and run the pencil along on the inside of the string and the mark will be the ellipse; 3 and 4 show position of pencil and string on the curve.

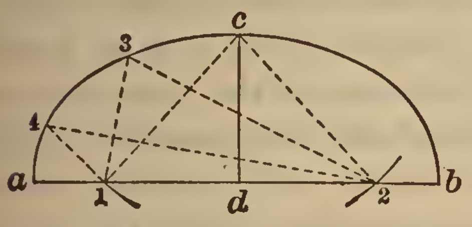


Fig. 71.—Drawing Ellipse with String.

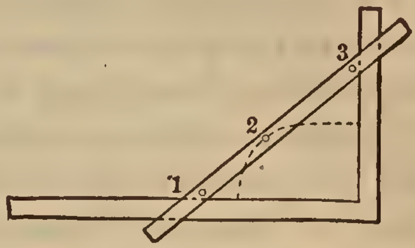


Fig. 72.—Drawing Ellipse with Square.

To Draw an Ellipse with the Square.—Take a strip of wood, as shown in Fig. 72, say $\frac{1}{2}'' \times 1''$, to use as a rule; then drive a nail through the stick about an inch from one end, as **1**; then make the distance between 1 2 equal one-half the short

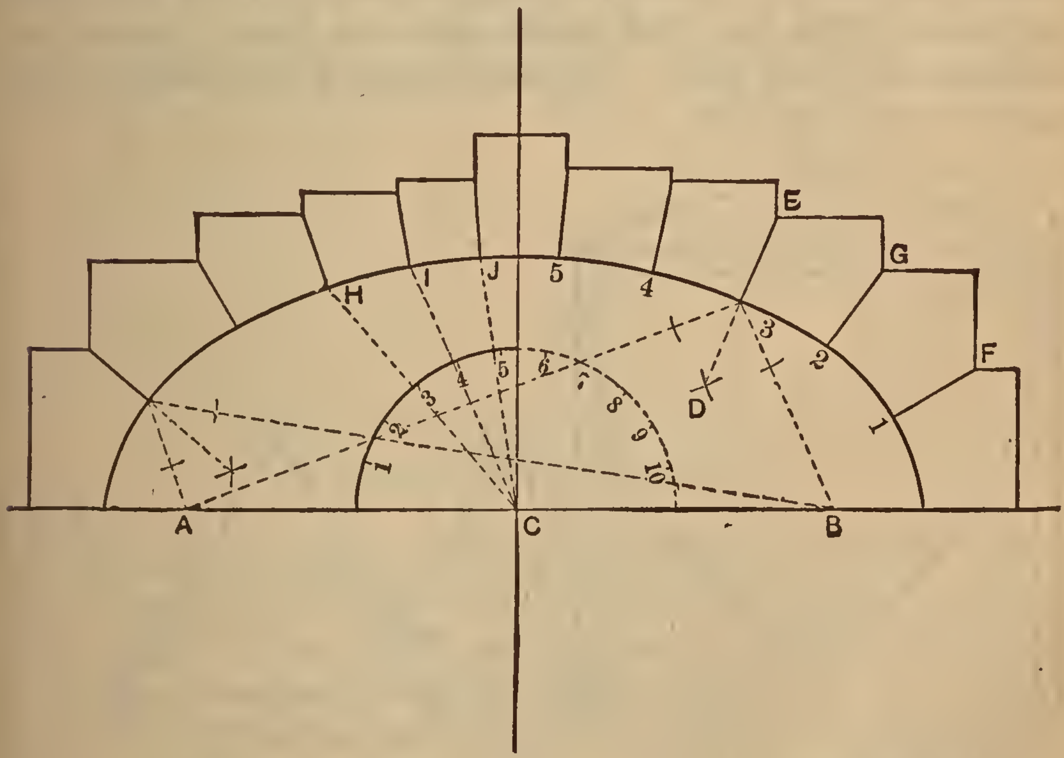


Fig. 73.—Voussoirs of an Elliptical Arch.

diameter of the llipse and 2 3 equal to one-half the long diameter; drive another nail at 3, and at 2 make a hole for a pencil, place the pencil in the hole and slide the stick from a perpen-

dicular position to a horizontal one, keeping the nails against the inside of the square, and the pencil will describe an ellipse

TO LAY OUT THE VOUSSOIRS OF AN ELLIPTICAL ARCH.—There are two methods of laying out the voussoirs of an elliptical arch, as shown by Fig. 73. In method A the voussoirs decrease in size towards the top of the arch, while in method B they are all about the same size.

To locate the joints in method A, use *C* as centre and strike a half-circle as shown, and divide the half-circle into as many equal spaces as there are desired voussoirs in the arch, always making the number odd so as to include the keystone. The divisions in this case being indicated by 1, 2, 3, etc., draw lines from *C* radiating through these points to strike the curve of the ellipse, as *H*, *I*, *J*, etc. This is the location of each joint.

In method B the curve of the ellipse is divided into as many equal spaces as there are desired voussoirs, counting the key as one.

To lay out the joints in either method connect the point of the joint on the curve with the two foci *A* and *B*, which are found as shown by Fig. 71; bisect the angle formed by these two lines, as shown by the line *D–E*, which gives the joint. Repeat the operation for each joint. The length of all joints should be the same, as *I–F*, 2–*G*, etc.

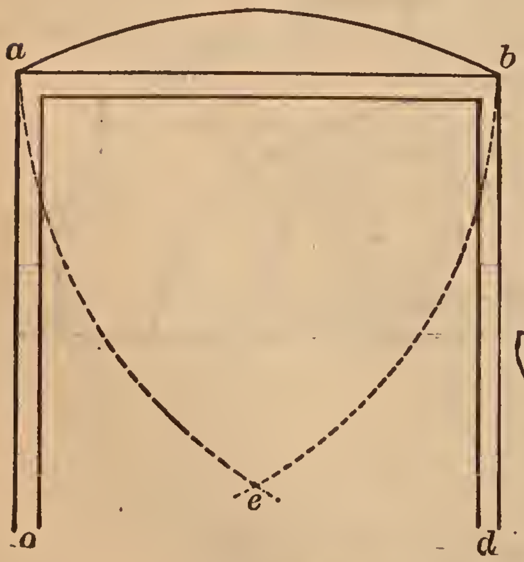


FIG. 74.—Arch Lintel.

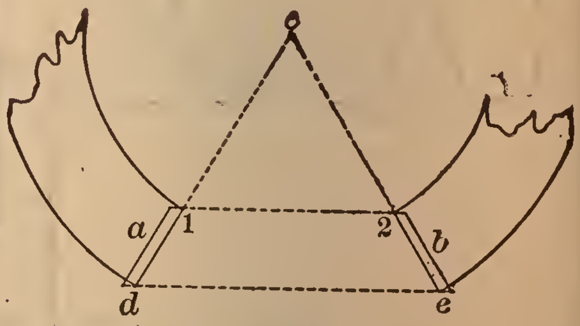


FIG. 75.—Splayed Jambs.

TO LAY OUT AN ARCH LINTEL.—The rule is to use the width of the frame as radius. Example: *abcd*, Fig. 74, represent the frame; now, with *a* as centre and *ab* as radius, draw the

arc *be*; with *b* as centre and same radius draw arc *ae*, and with the intersection *e* as centre and same radius draw the desired arc *ab*.

To Find the Pattern of Veneers for Circle-splayed Window- or Door-jambs.—Draw a section of the frame. as *a* and *b*, Fig. 75; then continue the lines 1*d* a d 2*e* until they meet at *c*, *ce* or *cd* is the radius to lay out the veneer.

Joints of a Gothic Arch.—The usual method of building a Gothic arch is shown by Fig. 76, the joints all radiating from the centres 1 and 2 used for striking the arch. This method requires the brick to be clipped at the top of the arch, as shown at *A*. If there is no weight on the top of an arch built in this way and there is much pressure on the sides there is a tendency to shove out the wedge-shaped bricks at the top and cause the arch to collapse.

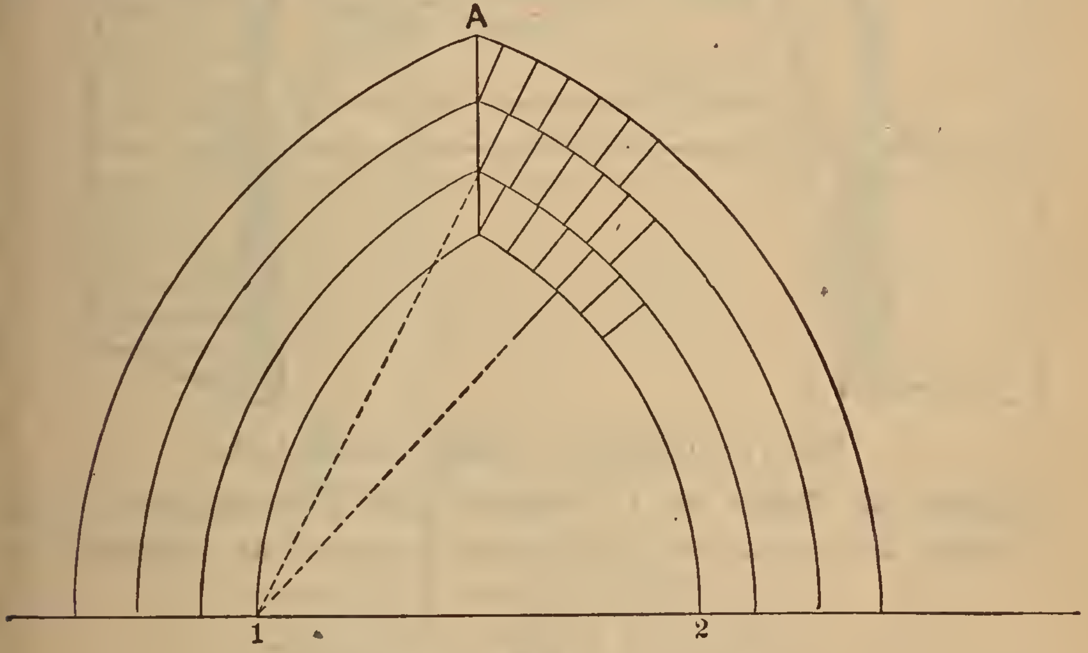


Fig 76.—Joints in Gothic Arch.

A method to overcome this fault is shown by Fig. 77. The arch is built in the usual manner, using the centres *A* and *B* for the radii of the joints until the arch has been completed about three-fourths of the springing distance, or to *A–C* and *B–D*. Now take the intersection of *A–C* and *B–D*, as *I* for centre, and radiate the joints for the balance of the arch from this point as shown. An arch built in this way will usually require special-shaped brick for the top part.

Dutch or French Arch.—Fig. 78 shows what is called a Dutch or French arch. It is built by clipping the brick as

shown. It is very weak and not much used in modern construction.

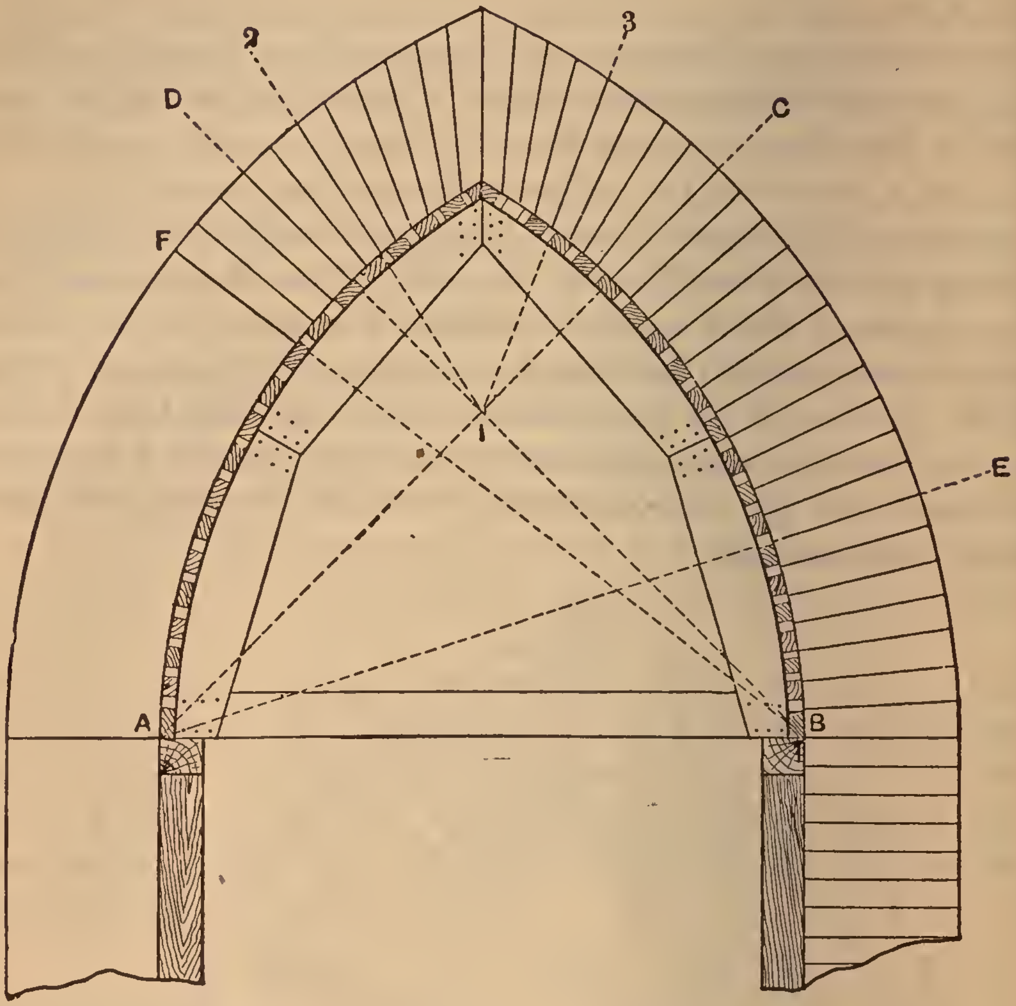


Fig. 77.—Laying out Joints of Gothic Arch.

Names of Parts of a Column and Entablature.—Fig. 79 shows the names of the various parts of an entablature.

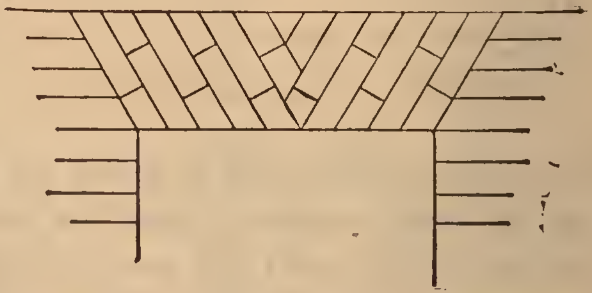


Fig. 78.—Dutch or French Arch.

The entablature being divided into three subdivisions, the cornice, frieze and architrave.

Fig. 80 shows the names of the various parts of a column. The column being divided into four subdivisions, the base, shaft, neck, and capital.

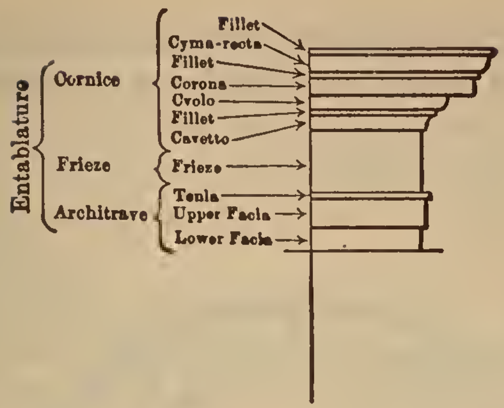


FIG. 79.—Names of Parts of an Entablature.

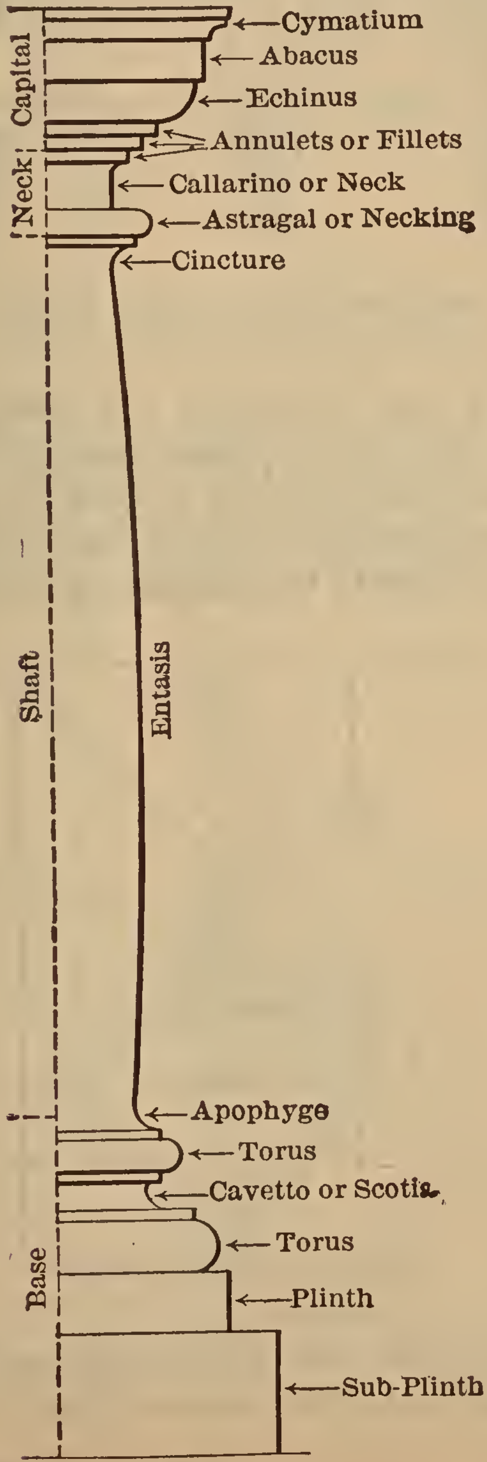


FIG. 80.—Names of Parts of a Column.

Spacing of Arch, Brick or Stone.—Before starting an arch of either brick or stone, the joints of the arch should all be

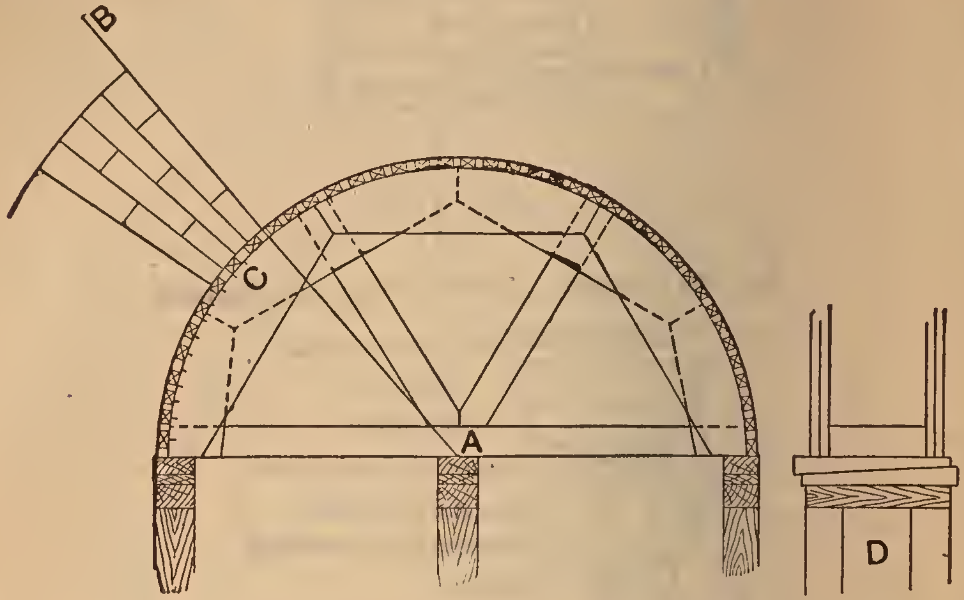


Fig. 82.—Spacing Joints of Arch.

spaced out with a pair of dividers and marked on t e centre as shown at *C*, Fig. 82. A short piece of line should then be fastened at the centre, as at *A*, and each course of brick or stone in the arch should be set to this line, which should be stretched taut and held to the joint mark on the centre.

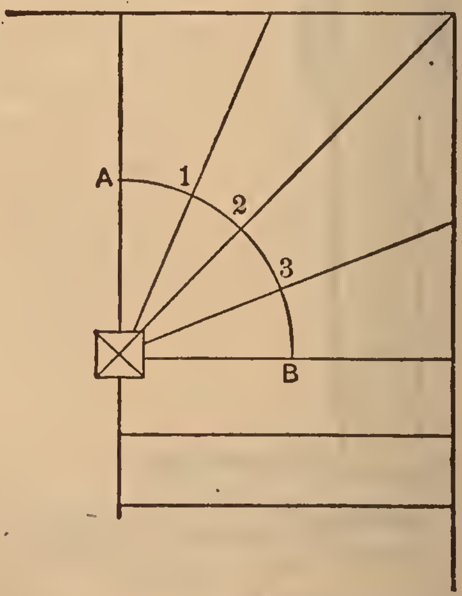


Fig. 83.—Winding Stairs.

By spacing the joints out in this manner there will be no trouble in putting in the last course or key.

To Lay Out Winding Stair-treads.—Make a drawing of the space to be taken up with the winders and draw an arc as *AB*, Fig. 83; divide this arc into as many equal spaces as steps desired, as 1 2 3, draw lines radiating from the centre of the newel through these points, which give the size and shape of the different steps.

To Square Across a Tapering Stick.—Place the square across the stick at the desired point, as shown by the dotted lines in Fig. 84, *A* being the point at which it is desired to square the stick. At the inside of the tongue of the square make a mark on the stick at a point one-half the distance

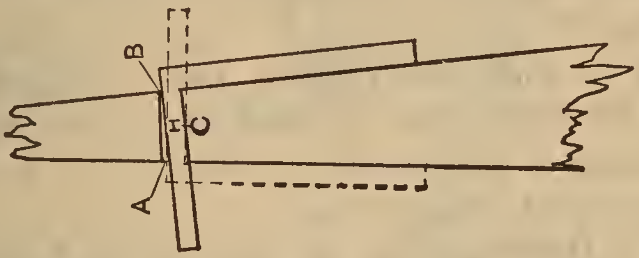


Fig. 84.—Squar ng Tapering Timber.

across the stick, as at *C*. In this case 4 being one-half the distance. Now reverse the square and put it on the opposite side of the stick, bringing 4 on the inside edge of the tongue to the point at *C*. Now draw a line from *A* to *B* which will be at right angles to the center line of the stick or square across.

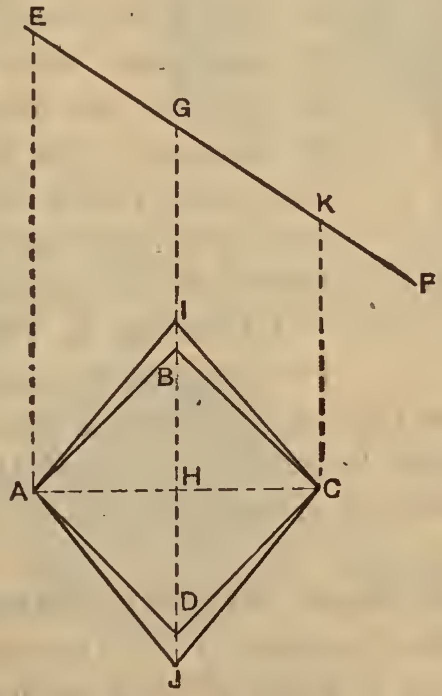


Fig. 85.—To Lay Out the Roof-hole for a Chimney.

To Lay Out the Roof Hole for a Chimney when Its Diagonal is Parallel to the Rafters.—Draw the square *A–B–C–D* and the diagonals *A–C* and *D–B*, Fig. 85, represent-

ing the chimney. Now draw *F–E* representing the slope of the roof, and erect the perpendiculars *A–E*, *B–G*, and *C–K*; on the middle perpendicular line make *H–I* and *H–J* each equal to *E–G*. Connect *A–I*, *I–C*, *C–J* and *J–A*, which gives the shape of the hole to cut in the roof.

SHORT CUTS, ETC.*

To Sling a Column.—Take two ordinary slings of equal length, weave them together, as shown by Fig. 86, and place them over the top of the column as shown by Fig. 87.

FIG. 86.

To Sling a Pole or Timber on End.—Fig. 88 shows how to hitch to a pole or timber to be hoisted on end; a hitch of this kind will not slip.

To Sling a Barrel.—Fig. 89, cuts 1, 2, 3, shows how to sling a barrel for hoisting mortar, etc., using an ordinary sling.

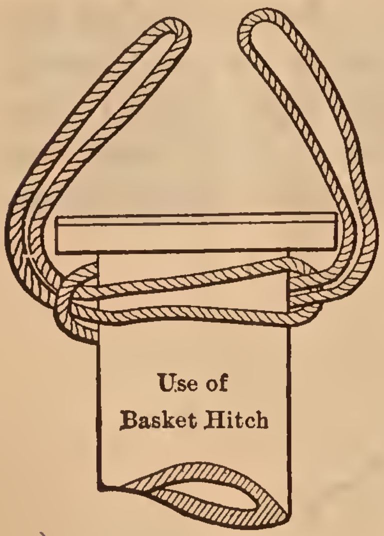


FIG. 87.

ANOTHER METHOD TO SLING A BARREL OR CAN.—Fig. 90 shows a ready way of slinging a can, to improvise a paint-pot, to dip for water, etc. Pass the end of the cord under the bottom of the can and bring the two parts over it, and make with them an overhand knot; open the knot, as shown in Fig. 91 and draw the two parts down until they come round the upper edge of the can; haul taut and knot them together again over the can, as shown in Fig. 90.

To Sling a Plank Edgewise.—The method of slinging a plank edgewise by a rope so that it will stay is shown in Fig. 92. A clove-hit h is made around the end of the plank, then one of the parts is twisted around the plank until the ends lead as shown.

To Shorten a Rope without Cutting.—To shorten a piece of rope without cutting it try the sheep-shank shown in Fig. 93. The rope is brought back on itself, making two or

* Several cuts in this part have been used by permission of the editor of *Practical Carpenter*.

more bights, and a half-hitch is taken around each bight. This knot will not slip, and will nearly fall apart of its own

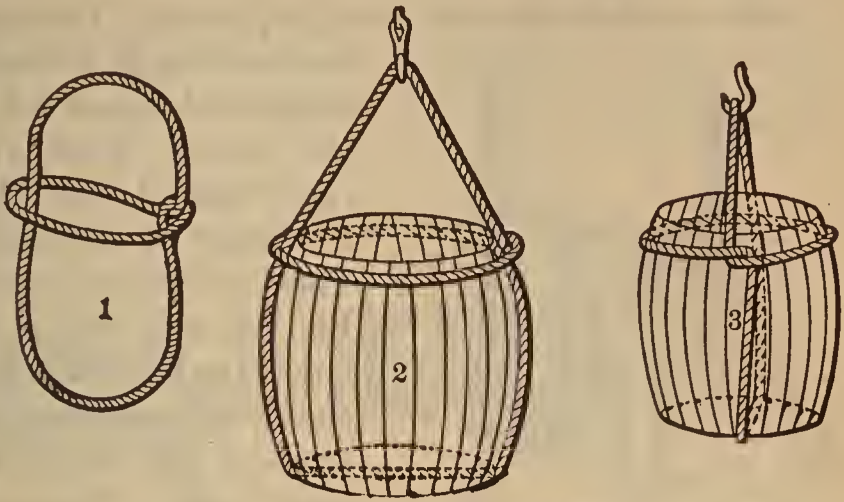


FIG. 89.—To Sling a Barrel.

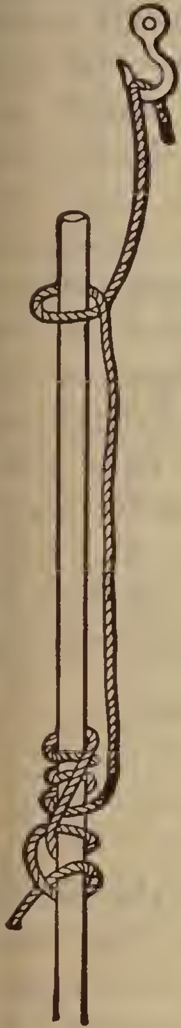


FIG. 88.—To Sling a Pole.

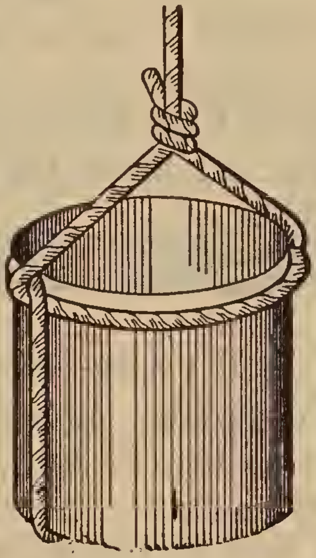


FIG. 90.—To Sling a Can.

accord if the strain is released, so that when there is a liability of this happening it is well to pass a piece of wood through the loop *A* at each end and pull the rope tight on them.

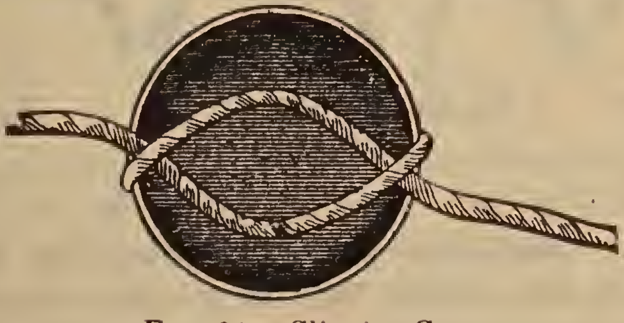


FIG. 91.—Slinging Can.

How to Tie a Jury-mast Knot.—This knot is also known as a masthead knot and a bottle-hitch, and is used at

the top of a temporary derrick in place of a mast iron to fasten the guys to.

Take a piece of stout cord and hold it between the thumb and forefinger of each hand, with a space of about 6 inches between the hands. Then twist the cord right-handed with the thumb and forefinger of the right hand only. This will throw up a bight like Fig. 94, with the part *A* under *B*. Grasp the loop thus formed between the thumb and forefinger of the left hand at the point where the two parts cross. Then move the thumb and forefinger of the right hand along the cord about 6 inches, and throw up another bight, laying it on top of the first one. You then have Fig. 95. Hold these two bights with the left thumb and forefinger, measure off another 6 inches, and throw the last bight. Place it on top of the last one made and you have Fig. 96. Take the part *E* in the last bight at Fig. 96, and, while holding the other parts in place, pass it under *B*, over *C*, and under *A*. This makes Fig. 97. Then take *B*, Fig. 97, and pass it under *D* and over *F*.

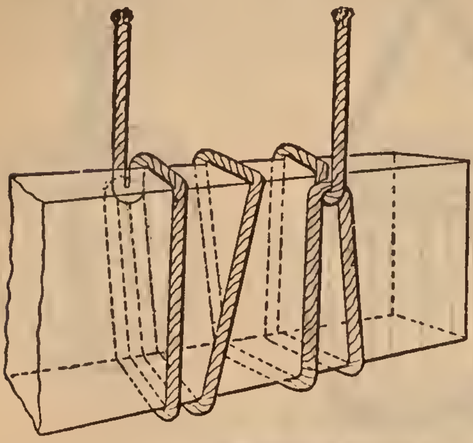


Fig. 92.—Slinging Plank.

Fig. 93.—Sheep-shank.

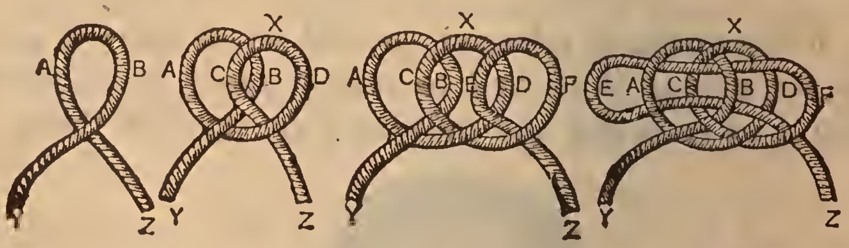


Fig. 94. Fig. 95. Fig. 96. Fig. 97.
Jury-mast Knot.

The result is Fig. 98. Then, while holding *E* in the left and *B* in the right hand, take hold of *X* with the teeth and pull it. The result will be Fig. 99. In practice, the part *O* in Fig. 99 goes over the reduced part of the mast- or derrick-head. The forestay is made fast to *X*; the stays to *B* and *B*; *Y* and *Z* form the backstays. Any strain on the stays tightens up *O*.

By pulling Y and Z in opposite directions the knot comes out. Every workman should know how to tie this knot.

Stop-knot.—Fig. 100 shows how to fasten a line to another on which there is a strain, such as a guy-line, etc.; this is often necessary when it is desired to tighten a guy-line. Take a smaller

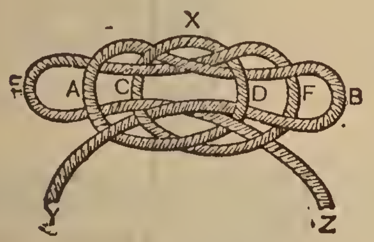


Fig. 98.—Jury-mast Knot.

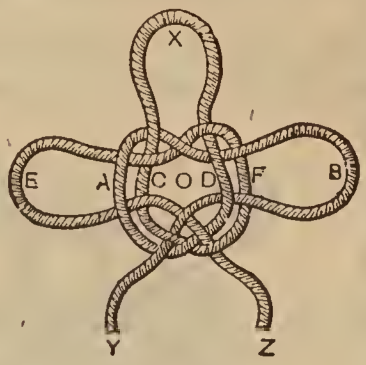


Fig. 99.

size rope, as A, and with the left hand hold it against the larger rope, and make three round turns toward the right of the larger rope. Bring the end of the smaller rope marked B back, and take three half-hitches to the left. Bring the end of the small rope marked A through the loop at C, and attach set of blocks to take the strain.

Another method of taking hold of a rope with a strain on it is shown by Fig. 101. Take a sling made of a smaller rope and

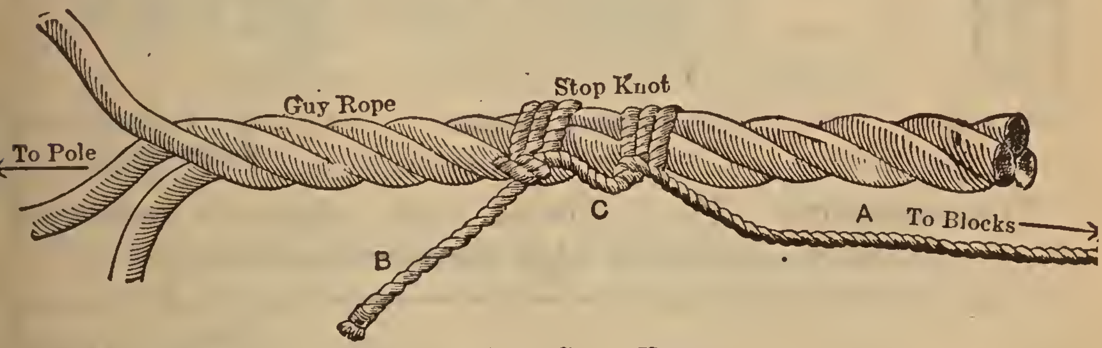


Fig. 100.—Stop Knot.

wrap it around by alternate cross-turns and attach blocks as shown.

To Sling a Plank for Staging.—Make a marlinespike hitch as shown by Fig. 102. Place the end of the plank in the bight occupied by the marlinespike; draw it taut, as shown by Fig. 103. with the double part of the bight on the under side of the plank.

Fastening for Ledger-boards.—Fig. 104 shows a method of fastening ledger-boards to posts or uprights by means of a wrought-iron clamp or stirrup. Two holes are bored through the upright, the stirrup inserted, and the ledger-board bolted fast as shown. *B* is the putlog laid in place. This method is quicker and stronger than nai s, and does not destroy any lumber.

Fig. 101.

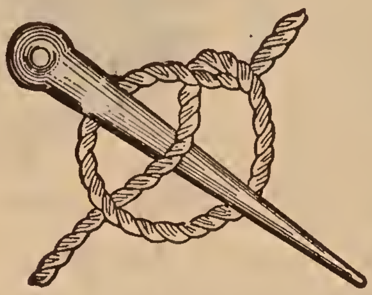


Fig. 102.

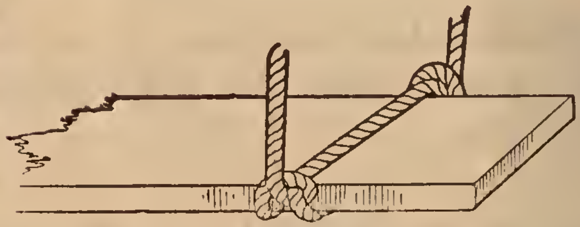


Fig. 103.—Slinging Staging.

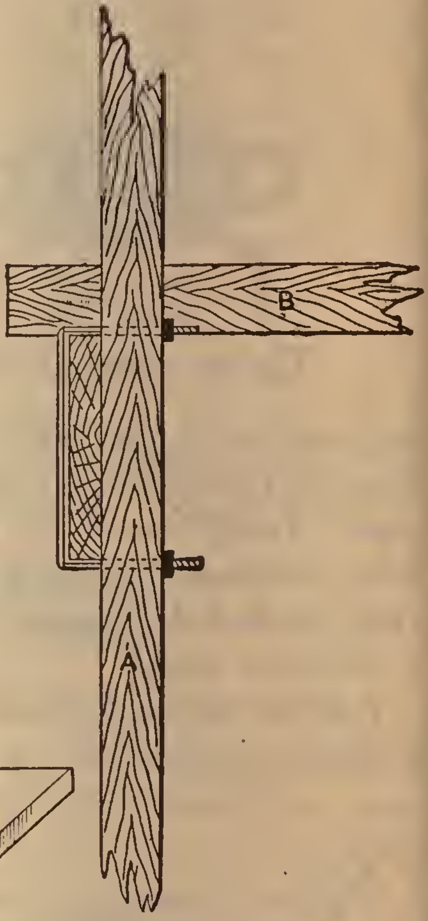


Fig. 104.—Ledger-board Fastening.

Temperatures.—The following table affords a somewhat rough method of estimating high temperature:

	Centigrade, Degrees	Fahrenheit, Degrees
Just glowing in the dark	525	977
Dark red	700	1252
Cherry-red	908	1666
Bright cherry-red	1000	1832
Orange	1150	2102
White	1300	2372
Dazzling white	1500	2732

Apparatus for Crushing Clinkers.—When screening cinders which are to be used as an aggregate for fire-proof concrete, all the large clinkers should be crushed to the desired size and used, as this is the material most desired.

A slat platform can be built by bolting together flat bars of iron, about 1″×2″, separating the bars about 1 inch with spreaders, as shown by Fig. 105.

A curb or box rim is then put around this slat platform as shown, and the platform set upon a couple of trestles about 2 feet from the ground.

The large clinkers are thrown in and crushed with a large flat hammer, or a flat iron concrete rammer. As the clinkers

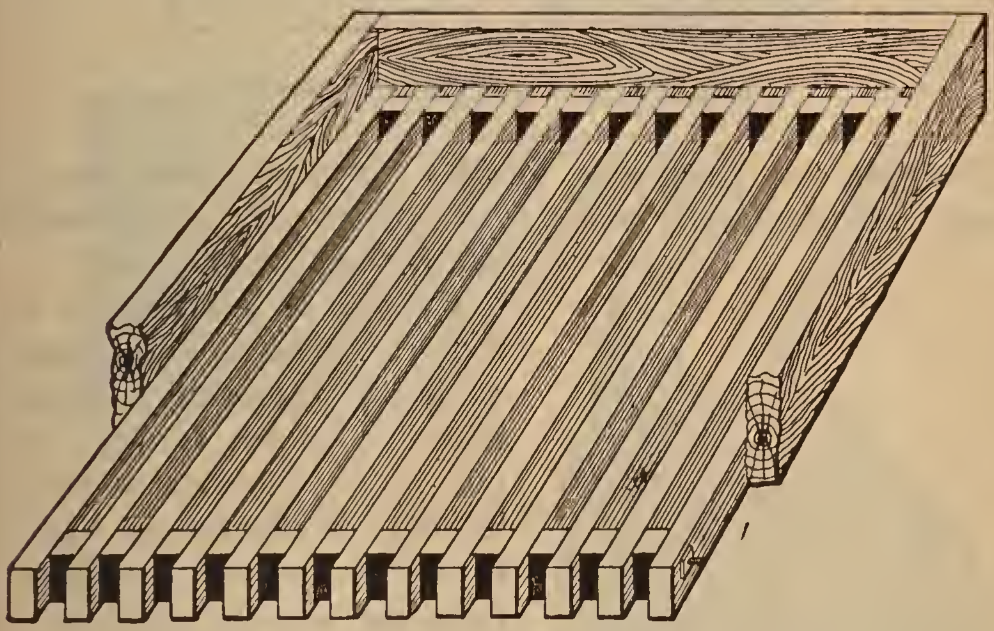


FIG. 105.—Apparatus for Crushing Clinkers.

are crushed to 1 inch or less, they fall through the slats to the ground.

Nailing-blocks in Concrete Work.—When doing concrete work, where any wood trim, base, or any other woodwork is to be used in finishing, provision must be made for nailing or fastening the trim, etc., in place.

Wood nailing-blocks made dovetail shape, as shown by Fig. 106, can be tacked on the forms where desired and the concrete tamped around them, and which, when hard, will hold the block solid in place.

The wood trim, etc., can then be nailed to the blocks, the dovetail shape of the blocks preventing them from pulling loose.

The blocks should be given a coat of paint or preservative to keep them from decaying.

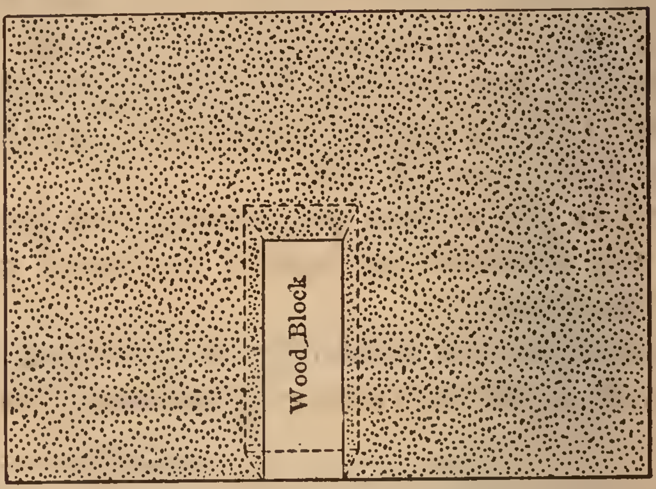


FIG. 106.—Nailing-block in Concrete.

Furring on Concrete Walls.—Concrete walls are often furred for plastering so as to overcome any dampness that might penetrate the wall.

When it is intended to fur a concrete wall, provision must be made as the wall is built for fastening on the furring. Bolts put in at intervals as the wall is built, as shown by Fig. 107, is one of the best methods for fastening on the furring. An ordinary carriage bolt is built in the wall letting the nut end project through the wood forms enough to take in the furring and bolt it fast as shown.

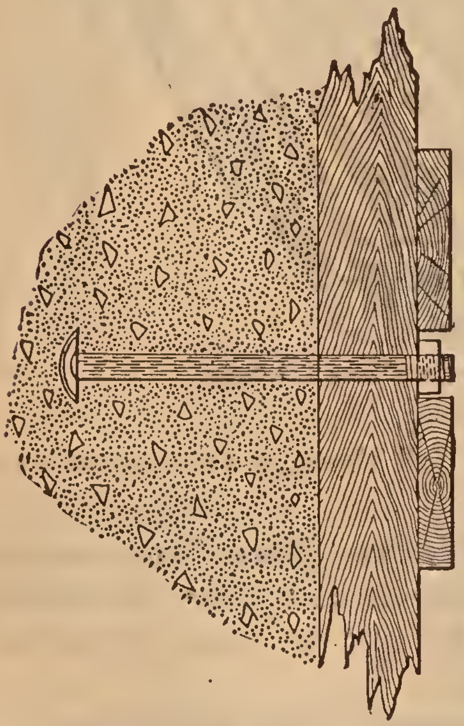


FIG. 107.—Bolt Fastening in Concrete.

The bolts must be put in vertical rows whatever distance apart it is desired for the furring strips, then the wood or metal lath is fastened to the furring after it is bolted in place.

Another method when metal lath is to be used is to build in the "Rutty" furring and nailing plug as shown by Fig. 108. This plug is built in the wall, as shown by Fig. 109, and the metal lath is secured direct to the plug with nails or staples.

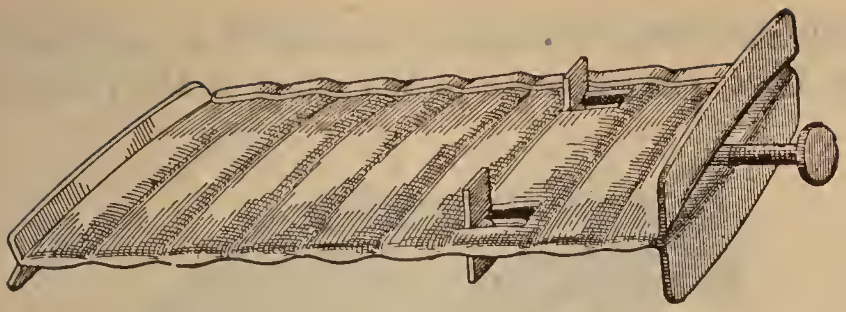


Fig. 108.—Rutty Non-furring Nailing Plug.

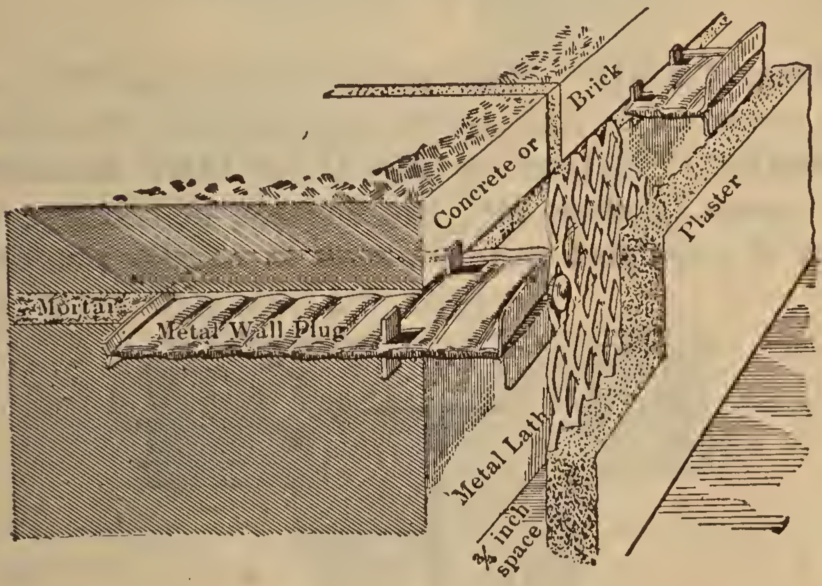
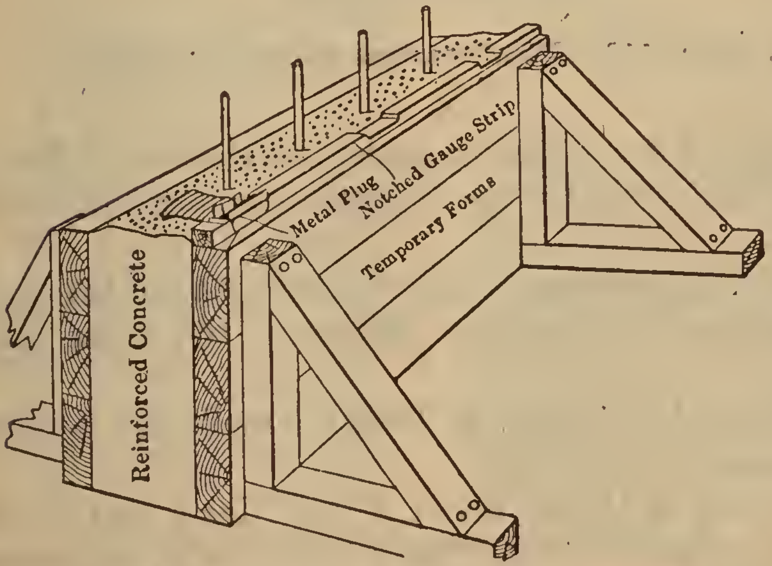


Fig. 109.—Rutty Non-furring Plug in Use.



AS USED IN CONCRETE CONSTRUCTION

Fig. 110.—"Rutty" Nailing Plug.

Fig. 110 shows how the plugs are placed in position as the walls are built, placing them in the joints of the plank forms.

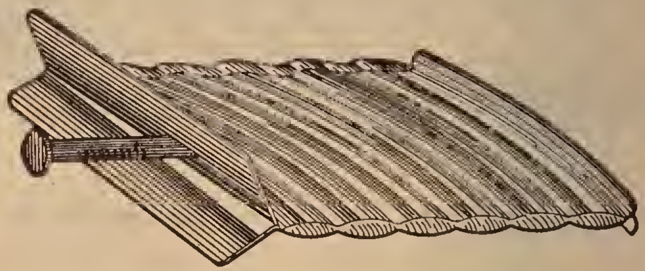


FIG. 111.—Rutty Steel Nailing Plug.

The ordinary "Rutty" plug, as shown by Fig. 111, can also be used, the wood furring strips being nailed to the plugs.

"Breaking" Expanded Metal or Wire Reinforcing.—When beams, girders, etc., are encased in concrete a reinforcement of expanded metal or wire is usually put over the

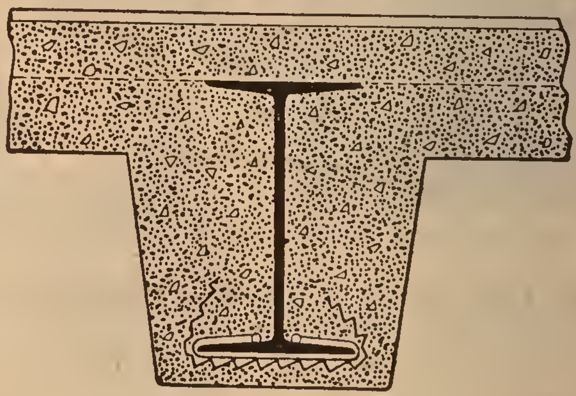


FIG. 112.—Reinforcement on Soffit of Beams.

lower flanges of the beam or girder, as shown by Fig. 112, so as to hold and reinforce the concrete forming the soffit of the beam.

The metal reinforcement should be bent in the form of a stirrup and put up over the flanges of the beam and wired fast.

Figs. 113 and 114 show a "break" made for bending such reinforcement.

Take a piece of timber about 4″×5″ for a bed plate as, *D*, and on top fasten a 2″×6″ or 3″×6″, as *B*, by hinging one end and fastening the other with a hasp and staple, leaving just space enough between the two pieces of timber to slip the metal under, as shown by Fig. 114.

This piece *B* is to clamp and hold the metal. Take another piece of 3″×6″, as *C*, Fig. 113, and hinge it at each end to *D*,

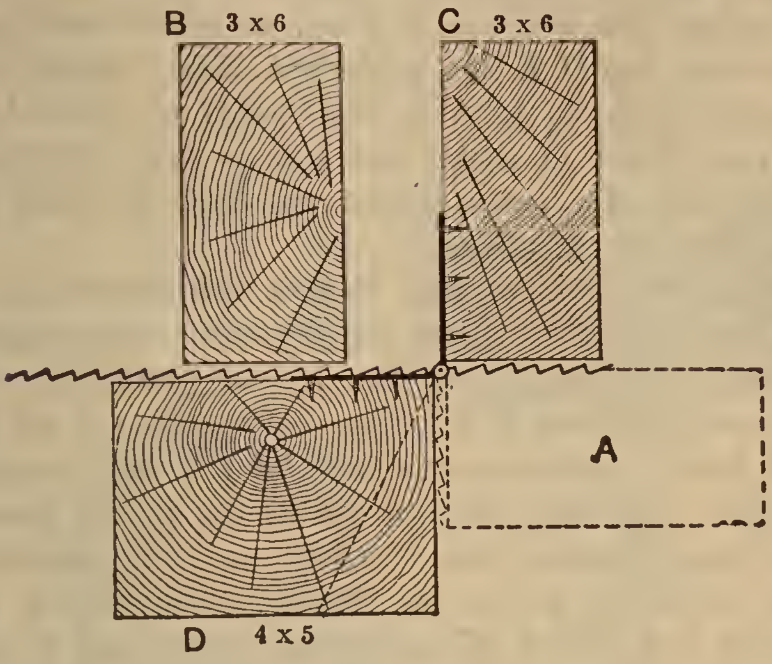


Fig. 113.—Section of "Break" for Bending Metal Lath.

as shown, setting the hinges so that it will clamp the metal tight when bent down to the position shown by the dotted

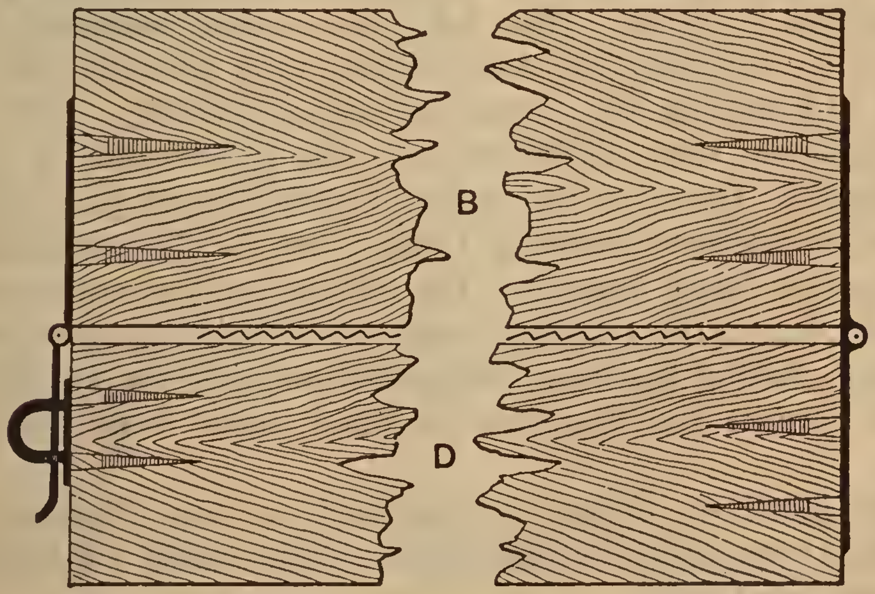


Fig. 114.—"Break" for Bending Metal Lath.

lines at *A*, Fig. 113. This "breaks" or bends the metal at right angles, or less as desired. If wanted to bend more than

at right angles, the piece *D* must be worked to the desired angle, as shown by the dotted line.

A strip of flat iron should be put on the corner of the bed plate *D*, where the bending is done, as much work will soon wear the wood round if not protected. The "break" must be made long enough to take in the metal of desired lengths. To form the stirrup of metal one side is bent, the lever *B* is then raised and the metal taken out and reversed and the other side bent where desired.

A Device for Measuring Water Admitted to a Concrete Mixer.—Fig. 115 shows an ingenious and simple water-gauging device for supplying the desired percentage of water to a batch of concrete in a mixer. An ordinary oil barrel is connected with a watter-supply tank by a 2-inch pipe provided with a valve. Through the bottom of the barrel passes a 2½-inch pipe, also provided with a valve, which is connected with the other valve by a rod, as shown. Telescoping into the 2½-inch pipe is a 2-inch plunger pipe, which can be raised or lowered by means of a lever. A stuffing box in the bottom of the barrel prevents leakage around the 2-inch plunger pipe. A ¾-in. "vent pipe" extends vertically from the head of the barrel up to the level of the water in the supply tank. Starting with the barrel full of water, the operator raises or lowers the 2-inch plunger pipe till the rod attached to it marks the desired percentage of water; then he pulls a rope attached to the lever that operates the two valves, thus opening the lower valve and closing the upper one simultaneously. The water in the barrel then discharges into the mixer until it reaches the level of the open top of the 2-inch plunger pipe, when of course no further discharge takes place. The operator then releases the rope operating the valves, and a counterweight (not shown in the drawing) pulls them back to their original position, closing the lower valve and opening the upper valve, which permits the barrel to be filled again from the supply tank.

This ingenious device is described by Mr. Clarence Cole, Assistant Engineer, in the report of the Chief of Engineers, U. S. A. for 1904.

To Prevent Boom of Derrick from Sagging.—When working a derrick with a long boom which is liable to sag in the centre or to buckle with a heavy weight, thread up the boom-line, as shown by the dotted lines at *A*, in Fig. 116, and

make the end of the line fast to the centre of the boom; this will take strain enough on the boom at this point to prevent all sagging.

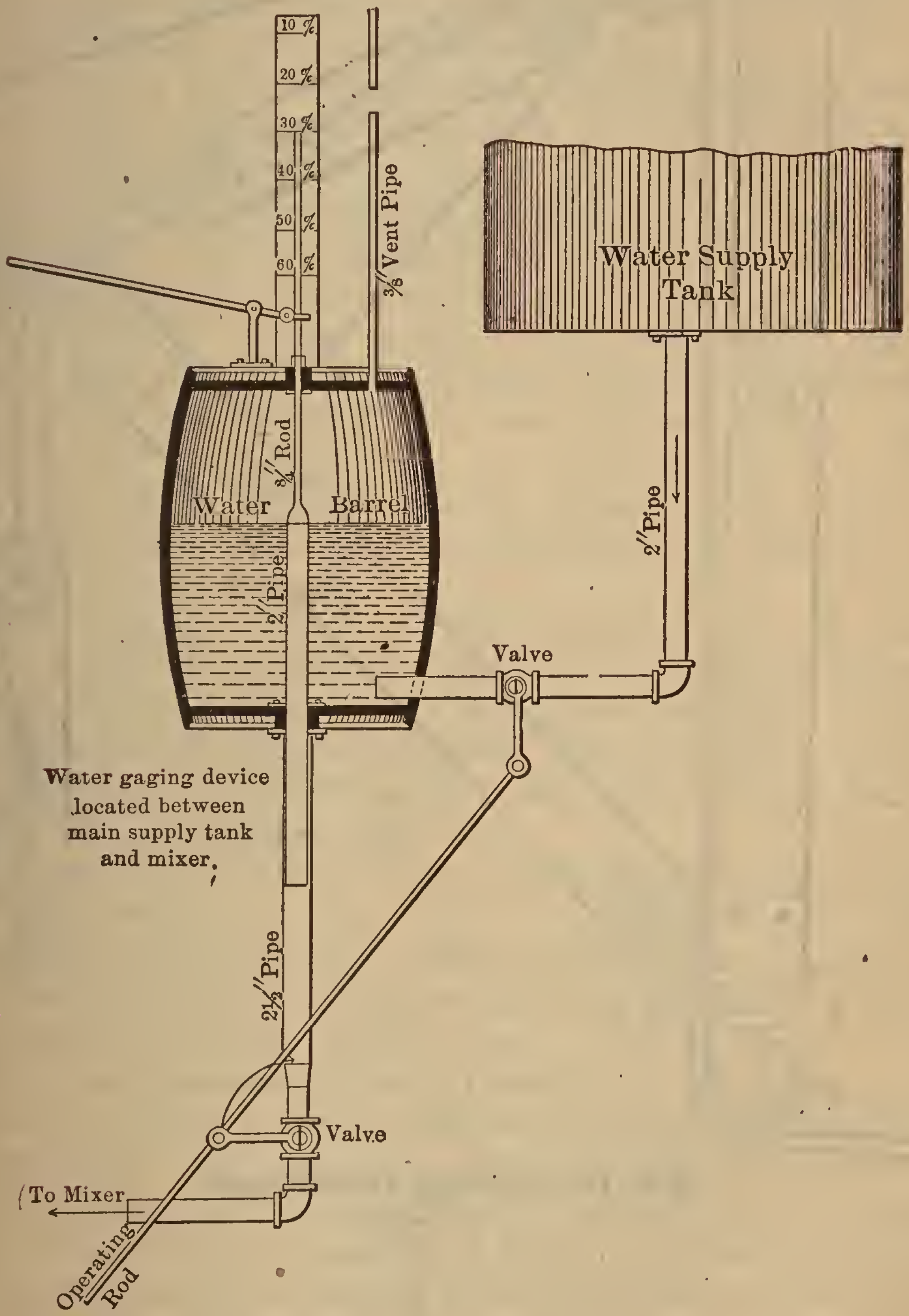


FIG. 115.—Apparatus for Measuring Water for Concrete.

TO USE THE SQUARE TO PLUMB WITH.—To plumb with a square set the blade of the square against the object to be plumbed and use the level on the tongue; when the tongue shows level the blade of the square will be plumb.

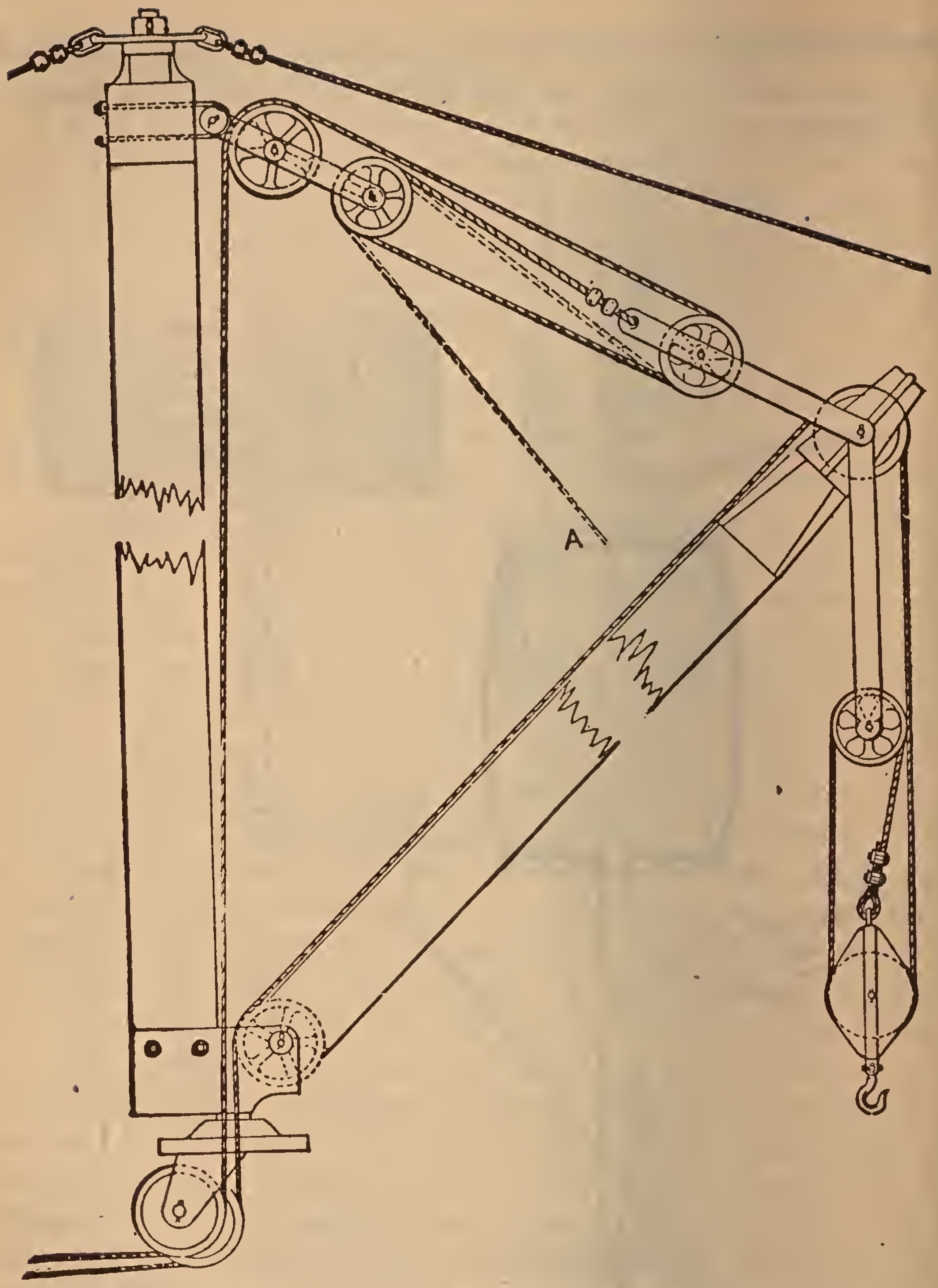


FIG. 116.—Stringing Derrick-boom.

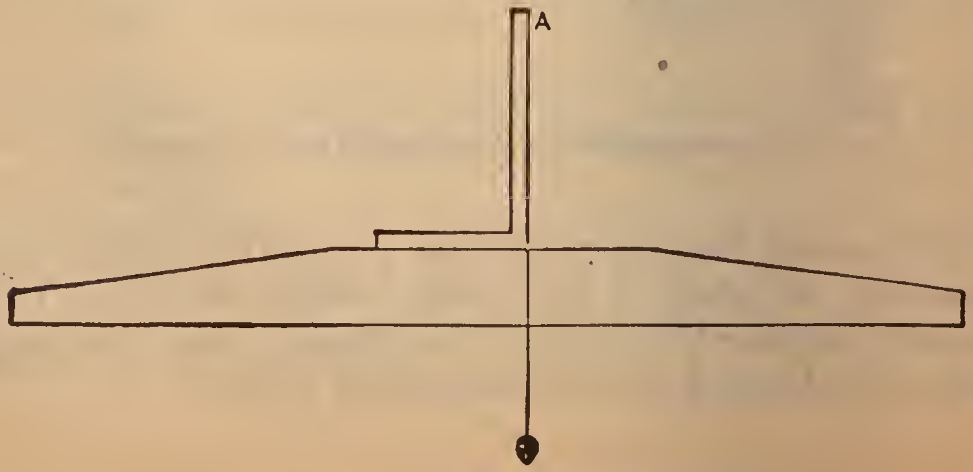


FIG. 117.—Levelling with a Square.

To Use the Square to Level with.—To level with a square and plumb-bob place the square on the straight-edge, as shown by Fig. 117, and drop the plumb-bob, holding the line at the top of the blade of the square, as at *A*, Fig. 117. With the eye sight the bob-line with the square, and they will show in line when the straight-edge is level.

Care of a Rope.—When coiling a rope always coil round to the right; this has a tendency to take out all twists and kinks, while if it is coiled to the left the coiling will twist and kink the rope. When rigging up a derrick or using ropes (except new ones) for any purpose, carefully examine them before putting them into use to ascertain their condition. Often a rope will look all right on the outside, while the interior of it may be rotten. Open up the twist of the rope and examine the different strands carefully in several places in the length of the rope.

Do not put a wet rope away in storage until it has been dried and aired well. A little precaution will lengthen the life of a rope considerable.

When opening a coil of new rope (especially wire rope) take the coil and run it along the ground like a wheel, letting the rope stretch out behind. This will prevent twists and kinks. After a hemp or manila rope has had some use it will be flexible enough to run directly off the coil, but a wire rope must always be run off, as explained above.

Several months' use of a rope usually decreases its strength about 40 per cent.

Setting Cement Blocks.—When setting cement blocks use a stone-cutter's mallet instead of a hammer and block of wood; it is much handier and will save time.

Tool for Rubbing Stone.—A handy tool for rubbing stone is made by taking a piece of cast iron about 10×12 inches and 1 inch thick. Lay the plate off into squares about $1\frac{1}{2}\times 1\frac{1}{2}$ inches, and at each interesection drill a $\frac{1}{2}$-inch hole. Around the plate put a rim extending up about 1 inch above the top of the plate, and put a handle on top of the plate to lift it by and to use in sliding the plate back and forth over the stone to be rubbed. Fill the plate to the top of the rim with sand and wet with water, and rub same as rubbing with a piece of stone. The sand will go down through the holes in the plate and cut very fast.

Mirror for Setting Capstone or Cornice.—When setting

the top or cap stone of heavy stone cornice the mason will have much trouble to look under the stone to note the position of it and see how the joints are.

A contrivance to overcome this difficulty is made by screwing a handle to a looking-glass, as shown by Fig. 118. The mirror can then be held below the stone and the reflection will

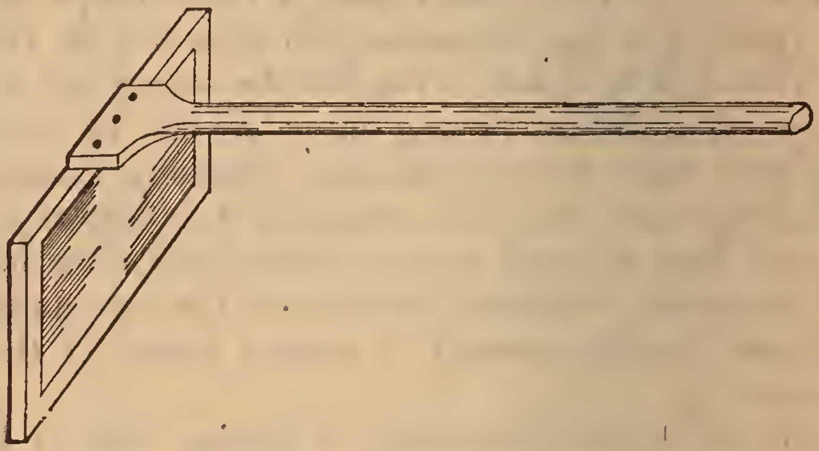


FIG. 118.—Hand Mirror.

show the soffit and joints beneath it, which cannot be seen from above.

The Steel Square.—The standard steel square has a blade 24 inches long and 2 inches wide, and a tongue from 14 to 18 inches long and $1\frac{1}{2}$ inches wide. The blade is at right angles to the tongue.

In the centre of the tongue will be found two parallel lines divided into spaces, Fig. 119; this is the octagon scale. The spaces will be found numbered 10, 20, 30, 40, 50, and 60. To draw an octagon, say 12 inches square, draw a square 12 inches each way and draw a perpendicular and horizontal line through the centre. To find the length of the octagon side place the point of the compasses on any one of the main divisions of the scale and the other point of the compasses on the twelfth subdivision; then step this length off on each side of the centre lines on the side of the square, which will give the points from which to draw the octagon lines; the diameter of the octagon must equal in inches the number of spaces taken from the square.

On the opposite side of the tongue will be found the brace-rule, Fig. 120. At the end of the tongue will be found the figures $\frac{24}{24}$ 33.95; the $\frac{24}{24}$ indicates the rise and run of a brace,

and 33.95 is the length. The rest of the figures are used in the same way.

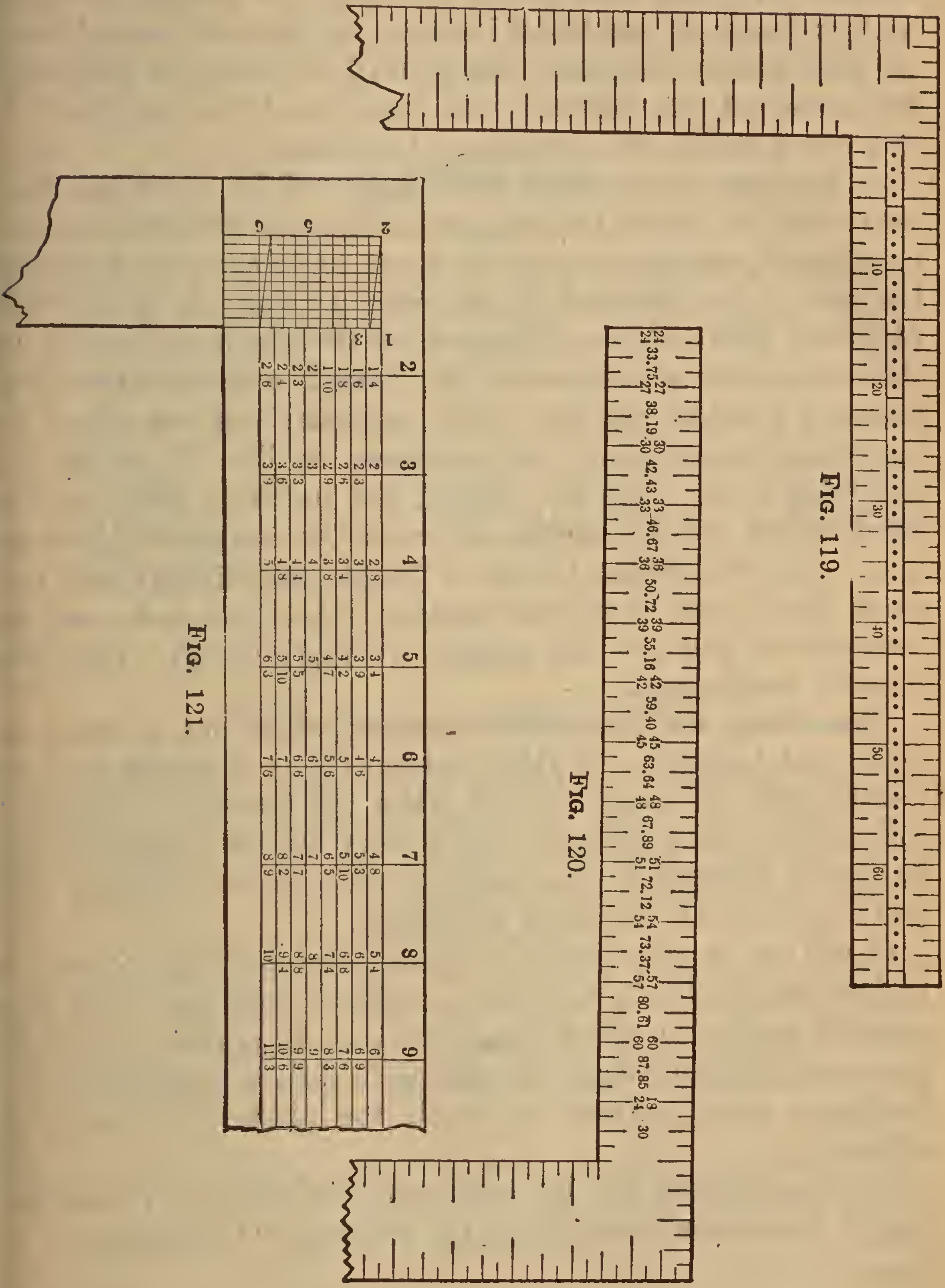


FIG. 119.

FIG. 120.

FIG. 121.

On one side of the blade will be found nine lines running parallel with the length of the blade and divided at every inch by cross-lines, Fig. 121; this is the board measure. Under 12

on the outer edge of the blade will be found the various lengths of boards, as 8, 9, 10, 11, 12, etc. For example, we will take a board 10 inches wide and 8 feet long; to find the contents we look under 12 and find 8 between the first and second lines; we then follow this space along until we come to the cross-line under 10, the width of the board, and here we find 6 8, or 6 feet 8 inches, the contents of the board.

At the angle of the blade and tongue will be found the diagonal scale, by which an inch can be divided into one hundred equal parts and any number of these parts can be taken from the scale. For instance, if we want to find $\frac{7}{100}$ of an inch place one point of the compasses on the diagonal line 2 3 at the intersection of the seventh line from 2, and the other point on line 1 2, which will give $\frac{7}{100}$ of an inch. To find $\frac{53}{100}$ of an inch place the point of the compasses on line 3 2, at the intersection of the third line from 3, and the other point on this third line at the intersection of line 5 5, which gives $\frac{53}{100}$ of an inch. The line 2 6 is 1 inch in length and divided into ten equal parts, then each part contains $\frac{10}{100}$ of an inch, and at the diagonal will give any number from $\frac{1}{100}$ to $\frac{10}{100}$. The scale is easily understood.

Plastering on Concrete.—Concrete when put in place in forms and tamped or puddled into place as it should be will usually show a smooth surface when the forms are removed; this surface being covered with a thin film of cement which has been brought to the surface through the tamping and puddling and the suction of the forms.

It will be found difficult to make plaster adhere to such a surface especially if a cinder or clinker concrete, and any concrete surface on which plastering is to be applied should be gone over and roughened by picking or with a pneumatic tool, to give a rough surface on which the plaster will key and adhere.

This roughening can be done very easily with a pneumatic tool if done immediately after the removal of the forms.

PART IV.

SIDEWALK CONSTRUCTION, CURBS, COPING, ETC., FINISHING THE EXPOSED SURFACE OF CONCRETE, EFFECT OF VARIOUS ACTIONS ON CONCRETE, VARIOUS USES OF CEMENT AND CONCRETE, TABLES FOR ESTIMATING CEMENT WORK, EXCAVATION TABLES.

SIDEWALK CONSTRUCTION.

Excavation.—Where frost has to be contended with the excavation for a sidewalk should be about 18 inches deep, and graded so that any water gathering in the foundation will be carried away. If necessary, drain tile should be put in at intervals to carry off this water.

In localities where frost and freezing does not occur the excavation need only be to the depth of the concrete of the walk, as an artificial foundation will not be necessary.

Foundation.—After the excavation is completed, the bottom should be tamped or rolled solid and then filled in with cinders, broken stone, or gravel to the line of the underside of the concrete of walk. This foundation should be tamped or rolled solid to avoid any settling after the walk is in place. If cinders or gravel is used it should be wet several times while being tamped or rolled, as the water will assist in compacting the mass.

When convenient, it is a good idea to put the foundation in place several weeks before laying the walk. Then any rain or walking over the foundation will help to pack it solid.

Forms.—After the foundation is in place and tamped, take 2″×4″ or 2″×6″ scantling, depending on the thickness of the walk, and put them in place to form the outside edges of the concrete. The top of the scantling should be set to the finished grade of the walk, as shown by Fig. 122. These scantling or stringers can be fastened by stakes driven on the outside and nailed to the stringer to hold it at the correct height. These stringers should be surfaced on the side and edge, so they will present a smooth surface to the concrete, and surfacing the edge straightens them.

Concrete Base.—After the forms are in place the concrete base, which should be a mixture of 1 part cement, 3 parts

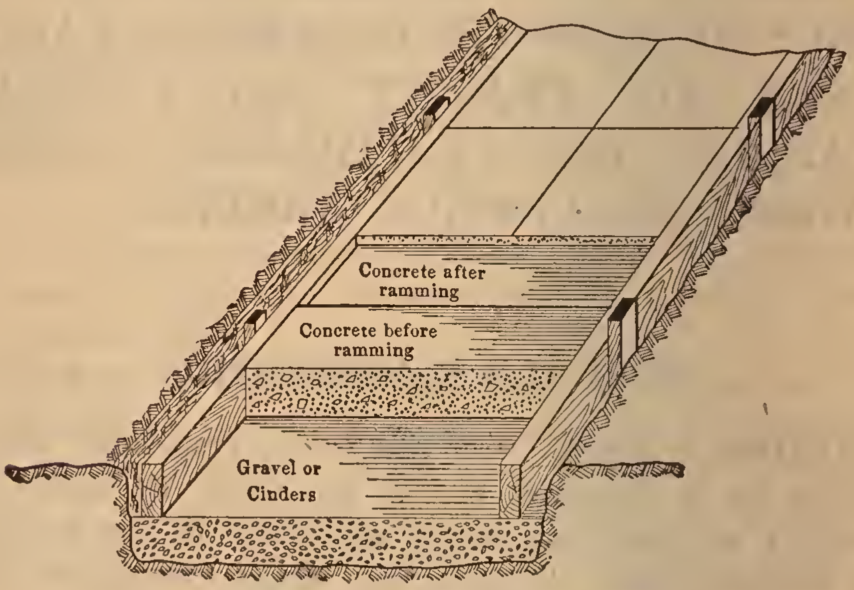


Fig. 122.—Sidewalk Construction.

sand, and 5 parts of broken stone or clean gravel, should be deposited in place. It should be mixed medium wet and struck off level with the top of the forms, after which it should be tamped thoroughly, which will cause it to compact and settle enough below the top of the form to give space for the thickness of the top or finishing coat, as shown in Fig. 122.

Mixing the Concrete.—Mix the cement and sand dry on a tight platform with shovels or hoes, until no streaks of the cement are visible; then add water in quantities to produce a mortar of the desired consistency, and thoroughly mix until a stiff plastic paste is produced. Uniform mixing prevents unequal contraction and expansion, thus preventing the concrete from cracking. Spread the mortar upon the platform, then add the proper quantity of broken stone or gravel which

has been thoroughly wet. This mass shall then be turned over with shovels or hoes not less than three times, or until every piece of stone is completely covered with mortar. The above should be sprinkled during mixing process.

Spreading Concrete.—This concrete should be immediately and evenly spread upon the cinder or broken stone foundation (which has been thoroughly dampened) in a layer of such depth that, after having been thoroughly rammed with concrete tampers, it shall be of the thickness required for the base.

When the walk is not over 6 feet in width and troweling can be done from both sides the walk can be laid in a continuous

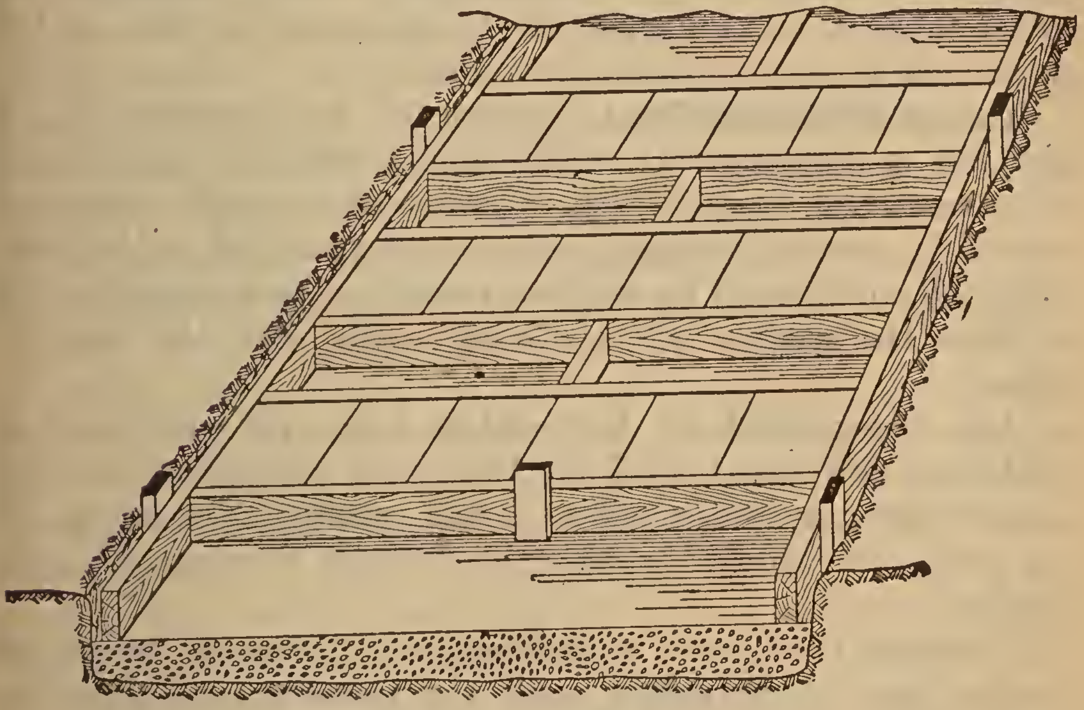


Fig. 123.—Method of Laying Wide Sidewalks.

stretch, but with a wide walk it should be laid in sections, as shown by Fig. 123.

Cross strips should be put in and every alternate section put in place and finished as shown. After these sections are hard enough to work on, the division strips can be taken out and the vacant sections filled in. This method is to be recommended, as it insures the separation of the blocks at the cross joints.

Cutting into Blocks.—When the base is put in continuous it must be cut at the line of the jointing of the blocks, which should be laid out along the stringer on each side of the walk.

This cut should extend at least two-thirds through the con-

crete and the crevice be immediately filled with dry sand to prevent adhesion between the blocks. Some workmen use a strip of steel about three-sixteenths of an inch in thickness to separate the blocks, filling the crevice with sand after the strip of steel is withdrawn.

Others prefer to put a strip of tar-paper between the blocks, and others put a strip of corrugated strawboard between the sections of the walk, the corrugated board being elastic takes care of all expansion.

Any method that cuts and separates the blocks can be used, but the blocks should all be cut and separated from each other, so that if there is any movement from frost, expansion, or other cause it will not crack the blocks across the face, as the block will be able to move at the joint.

Top or Finishing Coat.—Before the base concrete has set the top or finishing coat, which should consist of equal parts of cement and granite chips or coarse sharp sand, should be spread in place and tamped to remove all voids and air bubbles. This top coat should be wet just enough so that after tamping a little the mortar will strike off easily with the straight-edge.

After being struck off, it should be gone over with the float and then left stand until all the water disappears and the mortar becomes stiff enough to trowel smooth. The top should be given just enough troweling to bring it to a smooth, even surface.

Too much troweling is a detriment, as it brings all the cement to the top. In troweling, work the trowel in all directions so as not to cause any hollows. After the joints are laid out the tendency is to trowel from the centre of the block to the joints. If this is done the mortar is worked from the centre out to the edge of the block, and a hollow in the centre of the block is the result.

When troweling do not dust with dry cement to take up the water, but wait a little longer when the water will disappear, or if dusting is necessary and has to be resorted to, use equal parts of dry sand and cement. The dry cement if used by itself causes a mottled appearance on the face of the walk, caused by the dry cement forming little balls of neat cement mortar when coming in contact with the water. These balls will trowel out, showing spots in the finished walk.

The top coat should be cut through with the trowel immediately over the joints in the base, and finished with a jointing tool.

When the walk is to be gone over with a toothed roller to prevent it from becoming slippery the roller should be used just after the final troweling, the roller being run from one side of the walk to the other regardless of the jointing, using pressure enough to give the desired impression of the teeth of the roller. After using the roller go over all the joints with the jointing tool, which will give a plain margin around each block.

Another method to prevent the top becoming smooth and slippery is to float the top coat, and then with a wooden plate stipple it, giving it a rough surface. Or another effect can be obtained by laying a piece of leather or rubber on the floated mortar, pressing the leather or rubber down on to the mortar. Then take the sheet of leather at one corner, peel it off the cement, leaving a roughened surface.

Protection of Walk.—As soon as the top coat is hard enough to permit, the walk should be covered with a layer of sand about 1 inch or more in thickness, and this sand kept wet for four or five days. This will prevent the sun from drying the cement too fast and will cause the cement to become much harder than if left exposed to the weather.

A cement walk should be kept covered and not used for about ten days after completion.

Thickness of Walks.—Cement walks in ordinary places, such as residence districts, are usually laid 4 inches thick, including the top coat, but in business districts, or where the walk is of unusual width and much travel on it, the walk should be made thicker.

The following will give an idea of the thickness required for different walks.

Walks up to 5 feet in width should have a base of about 3¼ inches and a top coat of ¾ inch.

A 5-foot walk should have a base of 3¾ inches and a top coat of ¾ inch.

A 6-foot walk should have a base of 4¼ inches and a top coat of 1 inch.

A 7-foot walk, or over, should have a base of 5 inches and a top coat of 1 inch.

Size of Blocks to Cut Walks.—The size of blocks into which the walk should be cut will be governed by the width of the walk and the thickness of the concrete.

The walk should be laid out in blocks to look symmetrical and at the same time have the blocks small enough that there will be no danger of them cracking across the face.

A walk 3 feet wide and any thickness should be cut into blocks about 3 feet square.

A walk 4 feet wide and 4 inches thick should be cut into blocks 2×2 feet.

A walk 4 feet wide and 5 or 6 inches thick may be cut into blocks 4 feet square.

A walk 5 feet wide and 4 inches thick should be cut into blocks 2′ 6″×2′ 6″.

A walk 6 feet wide and 4 inches thick should be cut into blocks 3 feet square.

All 4-inch work should be cut into blocks 3 feet square or less.

A walk 4 feet wide and 5 or 6 inches thick should be cut into blocks 4 feet square.

A walk 5 feet wide and 5 or 6 inches thick should be cut into blocks 2′ 6″×2′ 6″.

A walk 6 feet wide and 5 or 6 inches thick should be cut into blocks 3 feet square.

All 5-inch work should be cut into blocks not over 4 feet square.

All 6-inch work should be cut into blocks not over 4′ 6″ square.

Coloring of Walks.—Walks are very often colored by adding some coloring matter to the top coat. This is done to overcome the glare of the sun shining on the light-colored walk when the cement is left its natural color.

The light reflected in this manner is very dazzling to the eyes. For the use of different colors see p. 78.

NOTES ON SIDEWALK WORK.—Use only the best of Portland cement.

Use coarse, sharp sand for the top coat, or if obtainable, use granite chips.

Do not use Puzzolan cement, as it will not stand the changes of temperature, and will disintegrate.

Do not use one kind of cement for the base and another for the top coat; their setting and action may be different.

Do not try to lay sidewalks in freezing weather, a bad walk is likely to be the result.

Always put on the top coat before the base concrete has set.

Do not use natural cement for the base and Portland for the top; they will not adhere together.

Do not use sand containing dirt or clay for the top coat.

Blisters or pock-marks are caused by air bubbles which have not been worked out of the top coat. Tamp the top coat enough to remove all air spaces and bubbles.

When walk is laid in hot weather cover immediately after finishing with a tarpaulin held up from the walk by stringers; then as soon as walk is hard enough, cover with sand as described.

Mix only enough concrete or top coat as can be put in place within an hour, and do not retemper or mix concrete that has started to set.

For mixing use clean water; iron in the water will give rust stains to the finished walk.

Lay a walk you can guarantee and stamp your name on it.

Do not use limestone aggregate for sidewalk work. Limestone expands on receiving moisture and contracts in drying, and this action will cause hair cracks.

To test the stone for expansion fill a lamp chimney with fine screenings; pack it solid, and then pour on water. If the crushed stone expands and breaks the lamp chimney it is unfit for use.

Large Cracks in Walks are Caused by:

Poor foundations, due to poor filling, poor tamping, or mixing of concrete.

Expansion and contraction when the blocks have been made too large or have not been properly separated.

Poor drainage, so that water will stand under walk and freeze in cold weather.

Roots of trees growing under the walk.

Shocks or too heavy strain before walk has had time to harden properly.

Hair Cracks or Small Surface Checks are Caused by:

Too much troweling, bringing neat cement to the surface.

Sprinkling neat cement on surface so that it may be finished sooner.

Exposing to hot sun or wind, causing it to dry out before cement has reached final set.

Using too much water in finish or top dressing.

Sprinkling with water after it has started to set, but before it has reached its final set.

Sprinkling with cool water while hot sun is shining on a walk that is only one or two days old.

Non-uniform Color and Streaks are Caused by:

Poor mixing of concrete and finish.

Using variable proportions of water.

Uneven troweling.

Troweling work after it has commenced to set.

Dust or clay in sand or water.

Dirty water dripping from tarpaulins or paper used for covering.

Freezing.

Unsound or Weak Work, Scaling, Swelling and Crumbling are Caused by:

Freezing of work done in cold weather.

Improper mixing and working of concrete and finish.

Using mixtures that have been allowed to stand too long, the cement in them having set.

Disturbing the work after the cement has set.

Cement being drowned by being submerged in water before it has reached its final set after being mixed and tamped in comparatively dry.

Putting finish on after concrete has set.

Getting dirt on concrete before finish is put on, and not giving walk enough water to enable it to harden properly.

Basement or Cellar Floor Work.—Cement floor work is done similar to sidewalk work, except that the concrete need not be quite so rich. For such work a base of 1 part cement, 3 parts sand, and 6 parts of stone or gravel, with a top coat of 1 part cement and 2 of sand will make a good floor.

Days' Work on Floors or Walks.—One finisher and four helpers will lay:

About 200 square feet of 8-inch walk in one day.
" 225 " " " 6-inch " " " "
" 250 " " " 4-inch " " " "

SPECIFICATIONS FOR SIDEWALK WORK

The following specifications are used by the city of Seattle, Wash., for sidewalks, etc.:

Concrete shall be mixed as follows: Upon a tight platform of evenly laid plank of sufficient size, a correct proportion of

gravel shall be evenly spread, and in no case more than 8 ins. deep. All material for concrete shall be accurately measured in suitable sized boxes. No counting by shovels or other

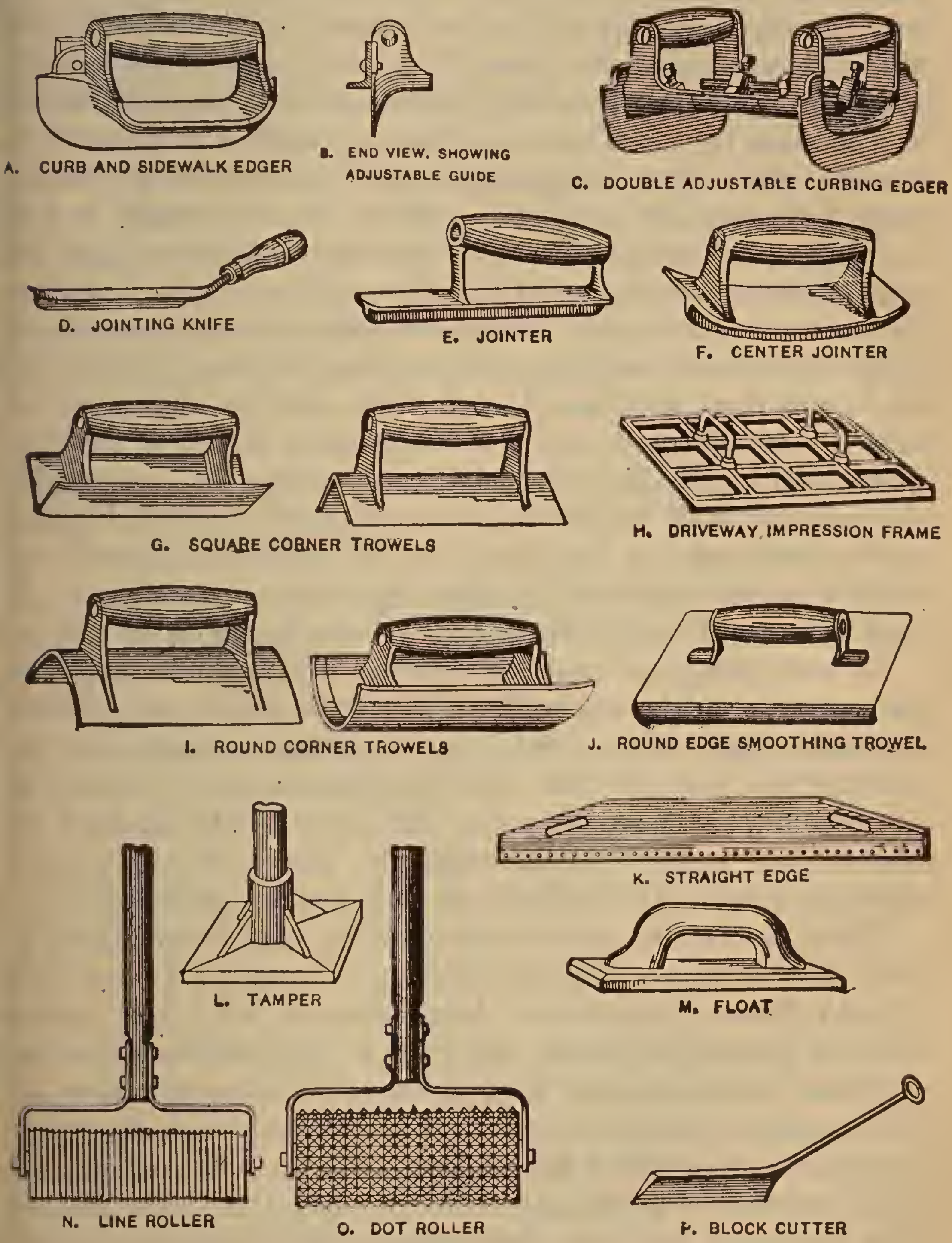


FIG. 124.—Tools Used in Laying Sidewalks, etc.

approximation will be allowed. To determine the proper proportions, a barrel of cement weighing not less than 400 lbs. gross shall be taken as measuring $3\frac{1}{2}$ cu. ft. In a separate box the correct proportion of sand and cement shall be mixed dry

until the whole mass is one even color. The gravel shall then be wetted and the mixture of dry sand and cement shall be evenly spread over it. Commencing at the corners, the men shall, with shovels, turn the mass over away from the centre, and coming back, turn it to the centre. In addition to the thorough wetting of the stone, if, in the judgment of the city engineer, it will be necessary, sufficient water shall be added to the mass by a rosehead sprinkler to enable the material to become thoroughly incorporated, and the process of mixing shall be continued until the surface of each stone is well covered with mortar. The concrete shall be spread upon the foundation as soon as mixed in a layer of such depth that after having been thoroughly compacted with iron-shod rammers, 7 ins. square and weighing not less than 40 lbs., it shall not be in any place less than 3½ ins. thick, and the upper surface shall be parallel with and not less than ½ in. below the proposed surface of the completed pavement. To insure this the concrete shall be struck with a gauge which shall be shod with a steel plate not less than ⅛ in. in thickness. Special care shall be taken to thoroughly tamp the concrete in all cases. It shall be tamped until a thin layer of water appears on the surface.

At such points as may be directed by the city engineer, and which shall be approximately 120 ft. apart, all concrete sidewalks shall have a joint ½ in. in width, extending entirely through the concrete base and wearing surface. As soon as the concrete is thoroughly set, this joint shall be carefully cleaned and immediately poured full, even with the surface, with hot grade "D" asphalt, or with pavers' pitch No. 6.

When the bottom course is completed, and before the concrete has begun to set, the finishing or wearing course shall be laid down. The correct proportions of sand and cement shall be thoroughly mixed dry until of one uniform color and sufficient water added to make a mortar of proper consistency. The mortar shall be colored by mixing lampblack therewith, at the rate of about 2 lbs. of lampblack to 1 bbl. of cement. This quantity may be varied to produce the shade desired. The lampblack shall be thoroughly mixed with the cement mortar in such manner as to produce a uniform and even shade satisfactory to the city engineer. Special care must be taken to thoroughly trowel down the mortar in order to secure a perfect bond with the concrete base. It shall then be care-

fully smoothed to a uniform surface, which must not be disturbed after the first setting takes place.

V-shaped grooves $\frac{1}{4}$ inch in depth shall then be made with a suitable tool, dividing the pavement into blocks 2 feet square. The thickness of the completed wearing surface must not be less than $\frac{1}{2}$ in. at any point. On steep grades the cement coating shall be roughened in such manner as the city engineer may direct.

When the sidewalk is completed it shall be covered with such material as may be directed and kept moist by sprinkling for at least one week. The sprinkling shall be done as often as may be necessary to keep the sidewalk constantly moist.

The contractor will be required to stamp his name in letters 1 in. high and $\frac{1}{4}$ in. deep twice in each block on each side of street.

All concrete shall be laid in short sections and immediately covered with the wearing surface. Retempering of concrete or mortar will not be permitted. All mortar or concrete that has begun to set before ramming is completed shall be removed from the work. Any concrete or mortar that fails to show proper bond, or that fails to set after, in the opinion of the city engineer, it has been allowed sufficient time, shall be taken up and replaced by the contractor at his own expense with new concrete or mortar of proper quality.

Granolithic Sidewalk.—The following extract is taken from specifications prepared and used by the supervising architect of the U. S. Treasury Department:

The sidewalk shall be of 4 ins. of concrete with 1-in. finishing coat laid on 8 ins. of broken stone or cinders, the stone or cinders to be well rolled or tamped before the concrete is laid. The concrete shall be composed of one volume of Portland cement, two volumes of sand, and three volumes of clean hard stone broken to pass through a 1-in.-mesh sieve. Lay off in rectangular slabs about 4 ft. square, the joints to extend at least half way through the concrete, and before the concrete commences to set spread the finish coat, composed of equal volumes of Portland cement and finely crushed granite, mixed with only enough water to dampen the mass, as dusting with dry cement in finishing will not be permitted.

Trowel to smooth even surface cut through on lines coinciding with the joints in the concrete and finish the joints with a V-shaped tool. Leave $1\frac{1}{2}$-in. margin around each slab.

In all work under the supervising architect samples of ma-

SPECIFICATIONS FOR CEMENT-SIDEWALK CONSTRUCTION IN VARIOUS CITIES.
(Compiled by Sanford E. Thompson.)

City.	Foundation.		Base.		Wearing Surface.			Dry Coating		Size of Blocks.	Guarantee, Years.
	Thickness, Inches.	Material.	Thickness, Inches.	Proportions.	Thickness, Inches.	Proportions.		Proportions.			
						Cement.	Sand.	Cement.	Sand.		
Boston	12	Broken stone, gravel, or cinders	3	1:2:5	1	1:1		......		Bet. 3½–6 ft. sq.	10
Rochester, N. Y.	6	Sand, gravel, broken stone, or cinders	†	1:5	1	2:3		......		....	3
Philadelphia, Pa.	3	Sand, gravel, broken-brick stone, or cinders	3	......	2	1:2		1:1		....	......
Washington, D. C.	0	....	4	1:2:5	1	2:3		1:1		....	5
Chicago, Ill.	0 or 12*	Cinders	4¼ av.	1:2:5	¾	1:1		......		5 ft. × 6 ft.	10
Milwaukee, Wis.	4	Cinders or broken stone	2½	1:3:5	1	1:1		......		Bet. 24–36 sq. ft.	......
St. Louis, Mo.	8	Cinders	3½	1:3	½	1:1		......		....	1
Omaha, Neb.	4	Gravel, slag, or stone	3	1:2:4	1	1:2		3:1		....	5

* Twelve-inch cinders required where the soil is not clean sand. † Specified for each contract.

terials to be used must be submitted and approved before the work is commenced.

Weight of Concrete:

Cinder concrete..........	about 105	lbs.	per	cubic	foot
Crushed-stone concrete...	" 140	"	"	"	"
Gravel concrete.........	" 150	"	"	"	"
Slag concrete...........	" 135	"	"	"	"

Quantity of Water for Mixing Concrete.—The amount of water to be used for mixing concrete can be determined only by experiment. The amount of water required depending on the dryness of the materials used and the wetness of the mixture required.

With materials under ordinary conditions the amount of water required will be about ten per cent by weight for a wet mixture of concrete.

CONTRACT AND SPECIFICATIONS FOR CEMENT SIDEWALKS, CLEVELAND, OHIO.

Contract for ....

This Agreement, Made this.............day of............. one thousand nine hundred and..........by and between the City of Cleveland, by the Board of Public Service, in that behalf, party of the first part, duly authorized by ordinance of the Council of said City, authorizing and directing the expenditure, passed .... and .... of .... Contractor, party of the second part.

Witnesseth: That the said party of the second part has agreed, and by these presents does agree, with the said party of the first part, for the consideration hereinafter mentioned and contained, and under the penalty expressed in a bond bearing even date with these presents, and hereunto annexed, to furnish at............own proper cost and expense all the necessary materials and labor in the........................ .... in conformity to the following specifications and plans of said work, now on file in the office of the Board of Public Service, and to the acceptance of said party of the first part.

SPECIFICATIONS.

Portland Cement Concrete Sidewalks to be Laid in the City of Cleveland, Ohio, Specification for 190 .

Portland cement concrete sidewalks to be laid as ordered in front of or along the sides of such lots or parcels of land, and upon such streets as the Board of Public Service may direct, during the period of one (1) year from date of approval of the contract.

Grading.—The contractor shall grade the surface of the ground on the lines of the walks to the grade given by the engineer, without any additional charge except in the case where the original surface of the ground would average for the whole frontage of the lot more than six (6) inches above or below the surface of the walks when laid, and in such cases where the average is more than six (6) inches the contractor shall be paid for the amount in excess of the said average of six (6) inches for the whole frontage of the lot, such price as the bids for extra excavation or embankment in his proposal.

Removal of Objectionable Matter.—If any material, vegetable, animal, or other objectionable matter be found in the line of the walk to be laid, it shall be removed, and the space filled with good earth, sand, gravel, cinders, or other suitable material, and carefully rammed. Stumps, rubbish or other matter which in the opinion of the inspector, is deemed unsuitable for filling material, will not be permitted in this work.

Concrete on Clay.—When concrete walks are laid on clay ground, an extra excavation of six (6) inches must be made, and the space filled with cinders, broken stone, slag or clean gravel. This to act as a foundation for the four and one-half inches of concrete in the sidewalk proper.

Bed.—Upon the sub-grade prepared as above there will be laid a bed of Portland cement concrete three (3) inches in thickness, after being rolled and rammed, to be made as follows:

The lower portion or bed of the walk to be one (1) measure Portland cement, three (3) measures clean sharp sand, thoroughly mixed dry and made into a mortar with as little water as practicable, and six (6) measures crushed blast furnace slag or broken stone, free from dust and dirt, then thoroughly mixed with the mortar by being turned over at least three (3) times. Slag or stone must be of such size as will pass through a one and one-half ($1\frac{1}{2}$) inch ring.

Coarse gravel may be used instead of broken stone or slag, and if coarse gravel is used, mixture to be one (1) part Portland cement and six (6) parts of gravel. The foregoing admixture to be placed in position and rammed thoroughly until the mortar flushes to the surface.

Wearing Surface.—The top finish or wearing surface to be one and one-half inches thick, and placed on top of the concrete as prepared above within 40 minutes after completion of bed or bottom. It shall be composed of one (1) measure of Portland cement and two (2) measures clean sharp sand, thoroughly mixed dry to the satisfaction of the Inspector, and then enough water added to make a paste of proper consistency; tamped same as the lower portion of the walk, and then floated or troweled to such finish as may be required by the Inspector.

All concrete shall be laid in short sections. No block to be larger than six feet by five feet.

All joints must be cut through the full thickness of walk, and the space made by the cutting tool ¼ inch in width must be immediately filled with clean dry sand and well rammed.

Any lack of compaction between the wearing surface and the bottom shall be deemed sufficient cause for requiring entire removal and the substitution of new and satisfactory work.

All concrete shall be mixed upon a tight wooden platform, evenly laid, and of sufficient size. All material shall be accurately measured in suitable sized boxes. No counting by shovels or other approximation will be permitted. To determine the proper proportions it is understood that one bag of cement weighing one hundred pounds shall be equal to one cubic foot of gravel.

Retempering of concrete will not be permitted. All concrete that has begun to set before ramming is completed shall be removed from the work. Any concrete that fails to show proper bond, or that fails to set after, in the opinion of the Engineer or Inspector, it has been allowed sufficient time, shall be taken up and replaced by the contractor at his own expense with concrete of the proper consistency.

All work while in progress must be protected by the contractor against injury from sun, rain, frost, or any other cause, and must not be opened for use until properly set. The Inspector may reject work where the wearing surface has become damaged or disfigured through lack of proper protection by the contractor.

Portland cement shall have a specific gravity of not less than three (3) and it shall leave a residue, by weight, of not more than eight (8) per cent on a No. 100 sieve, or twenty-five (25) per cent on a No. 200 sieve; said sieves having 100 and 200 meshes each way to the lineal inch, and the diameter of the wire composing same being approximately 0.0045 and 0.0020 inch respectively. It shall not contain more than four (4) per cent magnesia nor more than 1.75 per cent sulphuric anhydride, and it shall in other particulars conform to such chemical requirements as the Board of Public Service may deem necessary in order that the best grades only of Portland cement may be obtained.

Pats of neat cement one-half inch thick, with thin edges, immersed in water after hard set, shall show no signs of checking or disintegrating, and when submitted to a hot test, consisting of three hours in steam and three hours in boiling water, must give satisfactory evidence of soundness without cracking or blowing. Similar pats after standing in air shall exhibit no blotches, discoloration, or evidence of cracking, blowing, or disintegrating.

It shall require at least thirty minutes to develop initial set, and hard set shall not be taken in less than three hours, the test being determined by Gilmore wires. Briquettes of neat Portland cement with one square inch breaking section shall develop at least the following breaking strengths:

Neat Briquettes. Age	Strength.
24 hours (in water after hard set)	150 lbs.
7 days (one day in air, 6 days in water)	500 lbs.
28 days (one day in air, 27 days in water)	600 lbs.

Sand briquettes with one square inch breaking section, composed of cement one part and standard crushed quartz sand passing No. 20 sieve and resting on No. 30 sieve) three parts, by weight, shall develop at least the following breaking strengths:

Age.	Strength.
7 days (one day in air, 6 days in water).	150 lbs.
28 days (one day in air, 27 days in water)	225 lbs.

Cement which shows abnormally high strength on the one day or seven day tests may be regarded as unreliable, and may

be rejected therefor, the above, or any other test may be required as the Board of Public Service may direct.

Sand.—All sand shall be coarse, sharp, silicious sand, containing not more than five per cent, by weight, of loam or clay. It shall be free from organic matter or other impurities. It shall be stored on the work upon suitable wooden platforms, and shall in every way meet the approval of the Board of Public Service and shall pass a No. 10 standard testing sieve having ten meshes per lineal inch, and not less than thirty per cent shall be retained upon a No. 30 standard testing sieve having 30 meshes per lineal inch.

Gravel.—Gravel must be screened and washed, if necessary, but must be of such size that none of it shall pass a standard wire sieve having 10 meshes per lineal inch, and that the largest pebble shall not exceed one and one-half inches in greatest diagonal dimension may, upon the approval of the Board of Public Service, be used in lieu of or mixed in such proportions as it may determine with the broken stone. The pebbles composing the mass of gravel shall be so graded in size that the voids in the loose heap as determined by the Board of Public Service shall not exceed forty (40) per cent of the total volume. Should sand passing the said No. 10 standard testing sieve be contained in said gravel, the amount of sand used in preparing the mortar for the concrete shall be proportionately descreased. Crushed furnace slag conforming to the specifications for size and of a quality which will develop under test a crushing and transverse strength equal to that of the stone herein specified, may be substituted for broken stone in all concrete, except where additional specifications or notes on plans specifically call for broken stone or gravel. All stone, gravel or slag for concrete shall be stored upon suitable wooden platforms and must in every way meet the approval of the Board of Public Service.

Driveways.

Concrete.—All driveways used as such, if constructed of cement, must be at least six inches thick, four inches bed or bottom, and two inches top or wearing surface. Deep corrugations shall be cut in the wearing surface with proper tools, this to be done under the direction of the Inspector. In every other way concrete driveways shall be constructed in the manner as provided for concrete sidewalks.

Period of Guaranty.—The contractor must guarantee the sidewalks laid under this contract to remain in perfect condition for a period of two (2) years after the expiration of said contract, and the city will retain an amount equal to ten (10) per cent of the amount of the contract as a guarantee fund, that the contractor will lay, repair, or relay, any defective walks on receipt of notice from the Board, or its agents, so to do, and in the event of his failure to make such repairs, lay or relay such walks, said Board, without further notice, may proceed to make such repairs, lay or relay such walk, or cause the same to be done, whether by contract, or otherwise, at their option, and shall pay the cost of such repairs, laying or relaying from said guarantee fund.

At the expiration of said term of guaranty, said amount retained, plus interest, etc., less any expenses which the city may have incurred necessarily in connection therewith, shall be returned to said contractor as full payment of any balance due on said contract and improvement as herein provided.

SIDEWALK SPECIFICATIONS RECOMMENDED BY THE N. A. C. U.

The following specifications for sidewalks were prepared by the Committee on Streets and Sidewalks, of the National Association of Cement Users, and were presented at their convention at Chicago, Ill., 1907:

Foundations.—The ground base should be made as solid and permanent as possible. Where excavations or fills are made, all wood or other materials which will decompose should be removed and replaced with earth or other filling like the rest of the foundation.

Fills of clay or other material which will settle after heavy rains or deep freezing should be tamped solid in layers not more than 6″ in thickness, so as to insure a solid embankment which will remain firm after the walk is laid.

Embankments should not be less than 2½′ wider than the walk which is to be built. When porous material, such as coal ashes, granulated slag or gravel is used under drains, agricultural tile should be laid to the curb drains or gutters, so as to prevent water accumulating and freezing under the walk and breaking the blocks.

The position of shade trees should not be less than 4′ from

the walk. Carolina poplar, elm or other shade trees whose roots run near the surface of the ground should not be less than 10′ from the walk.

Line and grades should be given by a civil engineer; the stakes to be not over 25′ apart and far enough from the walk line so that an inspector may see that the walk is laid to line and grade.

The mould strips should be firmly blocked under the ends and the centre of the strips and carefully straight-edged, care being taken that the strips are parallel with the engineer's line and the height of the grade stakes. The walks should be laid with a drop of $\frac{1}{4}$ of an inch to the foot towards the curb gutter.

Specifications for Thickness.

The thickness of the walk should be determined by the location, the amount of travel and danger of being broken by heavy bodies falling on it, or frost.

Business front walks should not be less than 4″ thick, and may be 6″ thick with profit. The top coat of business walks should not be less than $1\frac{1}{4}$″ thick.

In residence districts, the top coat should not be less than 1″ wearing thickness and the thickness for different widths of walks should be as follows:

6′ wide, the minimum at the centres should be $4\frac{1}{2}$″ thick; at the edges, 4″ thick.

5′ wide, the minimum at the centres should be 4″ thick; at the edges, $3\frac{1}{2}$″ thick.

$4\frac{1}{2}$′ wide, the minimum at the centres should be $3\frac{3}{4}$″ thick; at the edges, $3\frac{1}{2}$″ thick.

4′ wide, the minimum at the centres should be $3\frac{1}{2}$″ thick; at the edges, 3″ thick.

All other widths less than the above, the minimum at the centres should be $3\frac{1}{2}$″ thick; at the edges, 3″ thick.

Sizes of blocks may be determined by the width and thickness of the walk. Business front walks should contain not over:

12 sq. ft. when the walk is 4″ thick.
16 sq. ft. when the walk is 5″ thick.
20 sq. ft. when the walk is $5\frac{1}{2}$″ thick.
25 sq. ft. when the walk is 6″ thick.

Residence districts where the walks are:

6′ wide, 3″ thick at the centre, the blocks may be 6′ long.
6′ wide, 4½″ thick at the centre, the blocks may be 5′ long.
5′ wide, 4½″ thick at the centre, the blocks may be 5′ long.
5′ wide, 4″ thick at the centre, the blocks may be 5′ long.
4½′ wide, 4″ thick at the centre, the blocks may be 4½′ long.
4′ wide, 4″ thick at the centre, the blocks may be 4′ long.
4′ wide, 3½″ thick at the centre, the blocks may be 4′ long.

Other widths less than the above, 4″ thick at the centre, the blocks may be 4′ long.

Other widths, 3½″ thick at the centre, the blocks may be 3½′ long.

Specifications for Concrete.

Bottom-coat Gravel.—The largest size to be not over 1″ and all under ⅛″ to be considered sand. Proportions to be one part high grade Portland cement to four parts, clean, hard gravel and sand enough to fill the voids, which makes the proportions, as most gravel will measure after being filled with sand, one part cement to five of the whole aggregate sand and gravel.

Bottom Coat Crushed Stone.—The size of broken stone should not be larger than ¾″ and vary in size to ¼″, and free from fine screenings and dust or soft stone. Proportions to be one part high grade Portland cement, two parts clean and sharp sand, and four parts broken stone, or what is termed by consulting engineers and concrete experts one part of cement to four of stone, and sand enough to fill the voids.

Mixing of both gravel and broken stone should be done by placing stone in the mixing box or on the platform first, then spread the sand evenly over the stone and in like manner the cement over the sand. Then cut through from top to bottom in thin slices, which will insure an even mix. Then turn with hoe or shovel twice before adding water, which should be done with a sprinkler and hoed over as sprinkled. The batch should be turned at least once after the water is applied. The amount of water used in the bottom coat should be only enough to make it, when firmly tamped, solid and not "quaky."

Top Coat.—Proportions, three parts high grade Portland cement and five parts clean, sharp sand mixed dry and screened through a No. 4 sieve. In the top coat the amount of water used should be just enough so that the surface of the walk

can be tamped, struck off, floated and finished within 20 minutes after it is spread on the bottom coat and when finished it should be solid and not "quaky." An edger of not less than 1″ radius should be used on the outer edges of the walk.

Separation of the blocks should be done with a spud not over 6″ wide and $\frac{1}{4}$″ thick, and to insure complete separation the groove should be cut through into the ground base. Fill the groove with dry sand before the top coat is spread and the top coat should be cut through to the sand after floating and troweling and a jointer run in the groove; then again draw a trowel through the groove, so as to insure a complete separation of the blocks.

The protection of newly finished walks from storms can be accomplished by covering with roofing paper or canvas. Canvas should never be laid on the walk, but stretched over on a slant, so as to run the water off.

Grading after the walks are ready for use should be on the curb side of the walk $1\frac{1}{2}$″ lower than the walk and not less than $\frac{1}{4}$″ to the foot fall towards the curb or gutters. On the property side of the walk the ground should be graded back at least 2′ and not lower than the walk, which will insure the frost throwing the walk alike on both sides.

Curbs, Coping, etc.—When putting down a cement curb the most important point is to get the form built straight and firm. This form can be built as shown by Fig. 125, using 2×4 inch stuff for the stakes.

The inside row of stakes, as at *A*, should be driven in line and the top anchored by a stay-board nailed to stake *C*, which should be driven deep enough to be very firm and solid. The stakes *A* can then be fastened in a perfect line and the planks for the inside form of the curb put in place, keeping the top of the planks to the exact grade for the top of the finished curb.

The row of stakes *B* can then be driven, leaving space enough for the curb and planks. The planks for the outside of the form can then be nailed in place and the stakes brought into line and fastened to the opposite stakes, as shown. The planks for the outside of the form should be surfaced, so they will leave a smooth surface to the concrete.

After the forms have been built the concrete can be mixed and put in place, tamping it solid in layers of about 6 inches, filling the form to the top before the bottom layers have set;

otherwise the tamping of the top layers would crack the bottom concrete that had already set. As the concrete is put in place, a mixture of sand and cement should be kept plastered against the face form.

The curb should be cut into lengths of about 6 feet, which can be done by putting in a partition in the form and putting in 6 feet of curb at a time and inserting a piece of tar paper in the joint. As soon as one section is filled and tamped solid, the partition can be taken out, leaving the paper in place and the next section filled in as before; or the curb can be filled in and then cut into lengths by driving a piece of sheet iron of about $\frac{1}{4}$ inch in thickness into the concrete, thus cutting it where desired. This sheet of iron should then be withdrawn

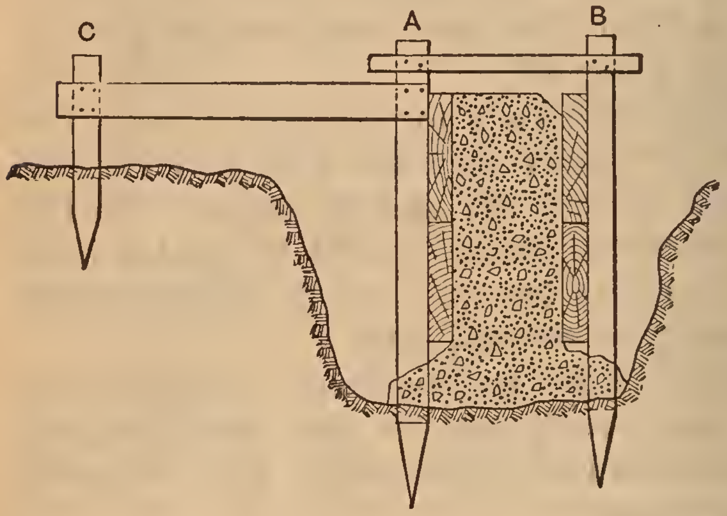


FIG. 125.—Forms for Curbs.

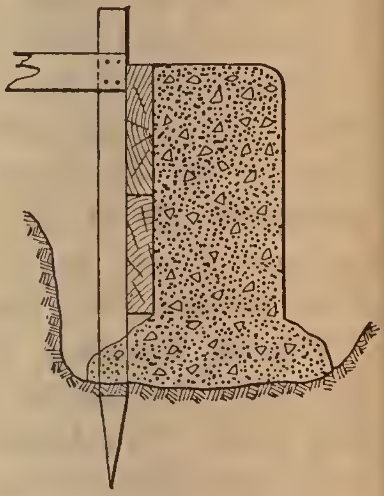


FIG. 126.—Finished Curb.

carefully and the cut made by it filled with dry sand. This will prevent adhesion between the two sections of curb.

The outside corner of the curb should be tamped to a bevel, as shown in Fig. 125, so the corner can be rounded off, as shown in Fig. 126. The top of the concrete should be finished with a mortar of sand and cement.

As soon as the concrete has set sufficiently, which will be in three or four hours, according to the quickness of the cement used, the outside form can be taken down and the face and top of the curb floated and finished, rounding the corner as shown. In case the working of the cement with the trowel brings too much water to the surface, sprinkle on a dry mixture of sand and cement to take up the surplus water. At each joint mark it off neatly with a jointing tool. If the curb is

to be rounded on both corners it can be shaped and rounded with a tool, as shown at *c*, Fig. 124, page 167.

STEELBOUND CURB.—This is a concrete curb having a steel bar imbedded in the concrete at the outer corner of the curb, as shown by Fig. 127. This bar is a protection to the curb and prevents the chipping off of the corner. After the forms have been built, as previously described, fill in with concrete to a height to receive the "corner bar," lay the bar on top of the frame, and with a properly shaped tool cut the concrete not less than 6 inches deep, at the *exact* point where the joint comes at the end of the bar. Into this cut sprinkle a little sand, and ram the concrete again, which will solidify the concrete and close the joint, except for the small sand cushion; use

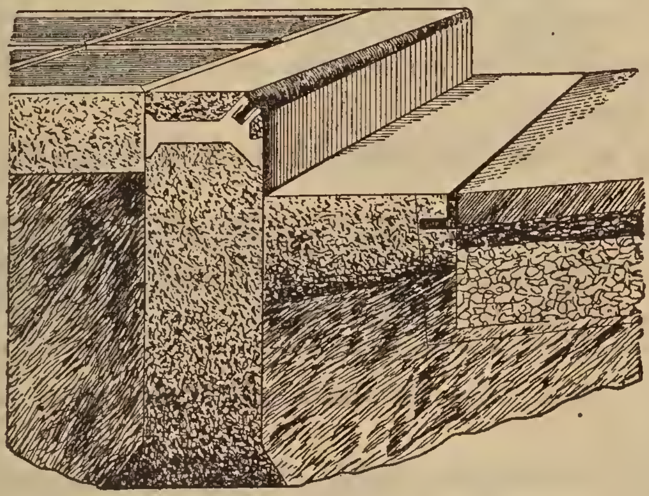


FIG. 127.—Steel-bound Curb.

care not to get sand on top of the concrete or it will cause a separation where you do not want it.

On top of the concrete now place the corner bar on which has been placed the iron brackets which hold it in place, wedging these brackets between the forms to hold them into position. A 10-foot bar should have one bracket in the middle, and one at each end, the end brackets also serving to hold the end of the next bar.

Set the bar level with the top of the form, which will be the finished top of the curb.

Before placing the bar into position, take a trowel and spread some fine top mixture of sand and cement along the top of the concrete in place, extending up the front plank to within about an inch of the top and beveled down to the concrete at an angle of about 45 degrees. Into this cushion of mortar

lay the bar, making sure that there is a surplus of mortar, which should squeeze out from under the bar, thus insuring a solid bed.

Next fill in behind the bar and on top of the concrete with a little more concrete to within about an inch of the top of the form; tamp carefully, and then put on the top mixture, work it well into place around the bar and trowel to a finish, as soon as stiff enough. At the end of each bar cut the concrete as deep as possible, without disturbing the bracket, and finish with a jointing tool.

One cement finisher and 3 helpers should put down about 60 feet of 8-inch curb in a day.

Finishing the Exposed Surfaces of Monolithic Concrete.—In monolithic concrete work the first step toward a satisfactory finished surface is to build the forms strong and rigid, so there will be no bulges or depressions in the finished face of the concrete.

The lining of the form should be 2-inch plank surfaced to a

Fig. 128.—Beveled-edged Planks for Forms.

thickness, and the edges slightly beveled, as shown by Fig. 128, so the plank will fit tight together at the joints.

When depositing the concrete, especial care should be taken to see that there is no voids near the surface or face of the wall, but the mortar part of the concrete should be forced out against the forms.

A good way to work the mortar out to the forms is to take a spade and work the blade up and down in the concrete next the form; this works out the voids and causes a smooth surface when the form is removed.

Another method is to have several sheet-metal forms made, as shown by Fig. 129. These forms are placed in position as shown, and the concrete filled in against them, and at the same time the space between the metal and wood form is filled with a face mixture of mortar. This face mixture can be mixed or colored, as desired.

After the concrete is filled to the top of the metal the metal form is withdrawn, and the concrete tamped solid. Then

the metal forms are again put in place and another layer of concrete deposited.

If there is no pressure on the concrete the wood forms can be removed in about 24 hours and the face of the concrete

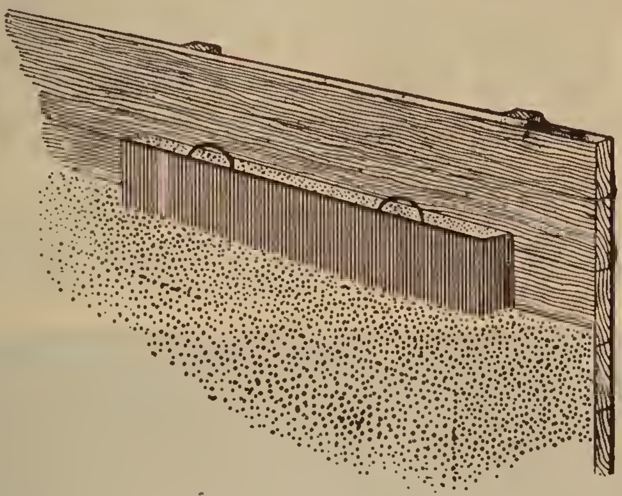
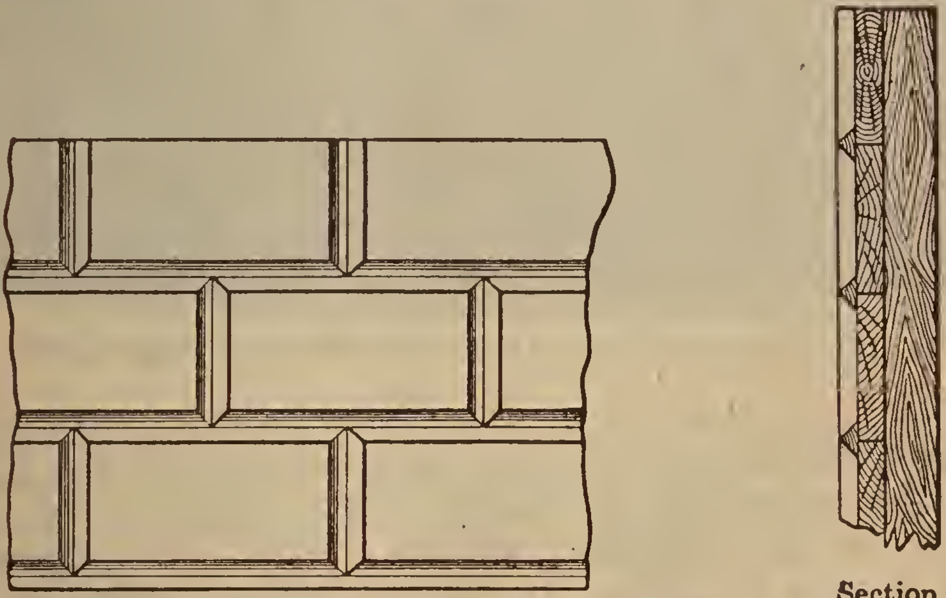


Fig. 129.—Method of Facing Concrete.

should be left comparatively smooth, and if gone over at once with a float and water, it should give a surface similar to sand finish in plastering. If the concrete is too hard for a wooden



Section.

Fig. 130.—Forms for V Rustication.

float to smooth off, use a brick of emery or a piece of sandstone.

After the surface has been floated off, it can be given a coat of cement grout mixed to the consistency of buttermilk, and which can be applied with a brush.

If it is desired to lay out the surface of the concrete in blocks with V-shaped rustications to imitate courses of stonework, these V moulds must be nailed on the inside of the forms before the concrete is placed, as shown by Fig. 130. The forms should be removed while the concrete is green, and the faces of the blocks floated as described, or a good finish can be obtained by going over the face lightly with a stone pick or tooth ax, giving the concrete the appearance of "picked" or "pointed" stonework.

Another method of facing concrete, which has been used quite extensively of late, is to use a desired aggregate for the

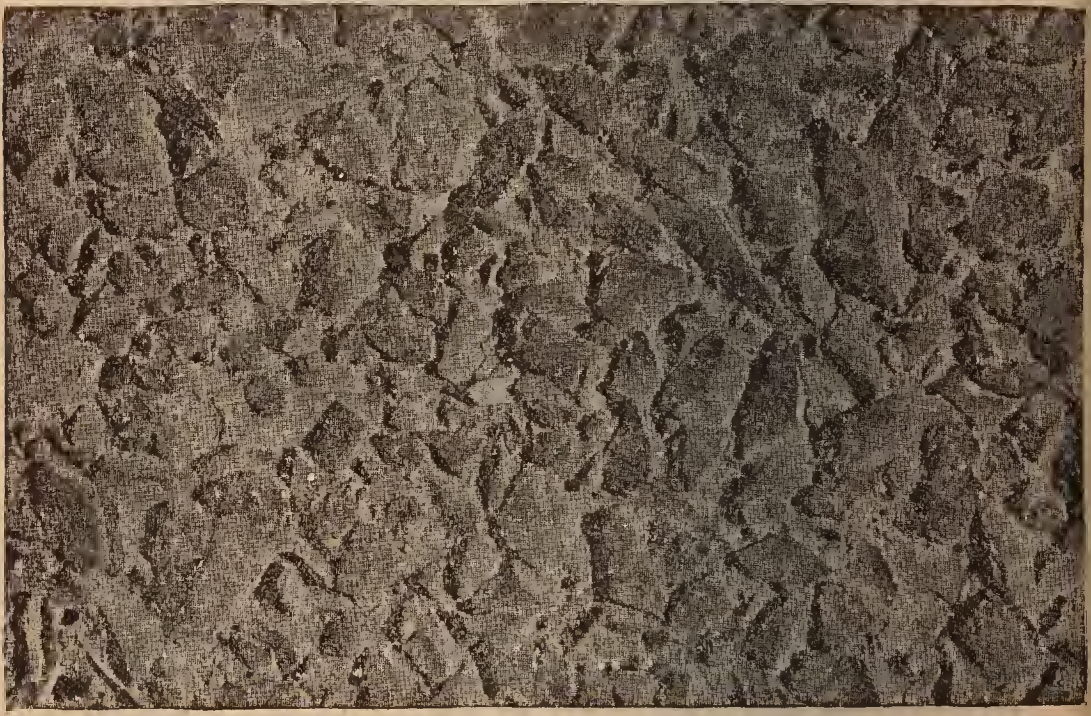


Fig. 131.—Surface of Broken Stone Concrete after being Washed.

concrete, and after it is in place about 24 hours, take down the form and go over the face of the concrete with a wire brush and water, scrubbing the cement mortar from the face and crevices of the aggregate until the pieces of the aggregate show in relief as desired. In this way different effects can be obtained, according to the aggregate used and the depth to which the mortar is scrubbed out.

Fig. 131 shows a concrete with an aggregate of broken stone, and Fig. 132 shows a concrete with an aggregate of screened gravel, both finished as described above.

The same result has also been obtained by washing the surface with an acid wash, which removes the cement and

exposes the particles of sand and aggregate. As soon as the desired effect has been obtained by the acid wash, the work is then washed thoroughly with an alkaline solution to remove the acid. It is then washed with clean water. The acid wash can be used on any concrete or cement work.

The wash is usually made of 2 parts water to 1 part hydrochloric acid, but the strength of the wash must be governed to suit the work it is used on.

Where the work is not extensive and an attractive finish is desired, pebbles of a certain size, say about 2 inches in diameter, can be placed against the form by hand as the concrete

FIG. 132.—Surface of Gravel Concrete after being Washed.

is put in place and the concrete tamped solid, filling the voids between the pebbles. The forms can be taken down and the face scrubbed with the wire brush, as described, giving a very unique effect.

The important point in the above methods of finishing is to remove the forms while the concrete is green, so the mortar can be scrubbed off with the brush.

The N. Y., N. H. & H. Railroad has adopted the following method of finishing the surface of concrete work done along its lines:

For abutment work the mixture employed is 1:3:6, and gravel is extensively used for the coarse aggregate; specifica-

tions require that not over 5 per cent should be less than ¼ inch in size, and the other limit is placed at 2¼ inches. For parapets, bridge seats, and arches, the mixture is made 1:2:4, and in all cases exposed surfaces are faced with a rich Portland cement mortar laid against the forms as the concrete advances Concrete on the exposed surfaces is rubbed down with bricks of carborundum, emery or grindstone to remove board marks and small irregularities, and the surface is then treated to a thin coat of rich Portland cement mixed thoroughly, rubbed in with wood or steel float trowel.

See page 67 for wash used by the Wabash Ry. for face of concrete work.

Tooling monolithic concrete also gives it a good appearance and takes off any irregularities caused by the swelling or buckling of the forms. The tooling can be done with a stone-cutter's crandall, or with a pneumatic tool.

Fire-resistance of Concrete.—The fire-resisting qualities of concrete depends to a large extent on the aggregate used.

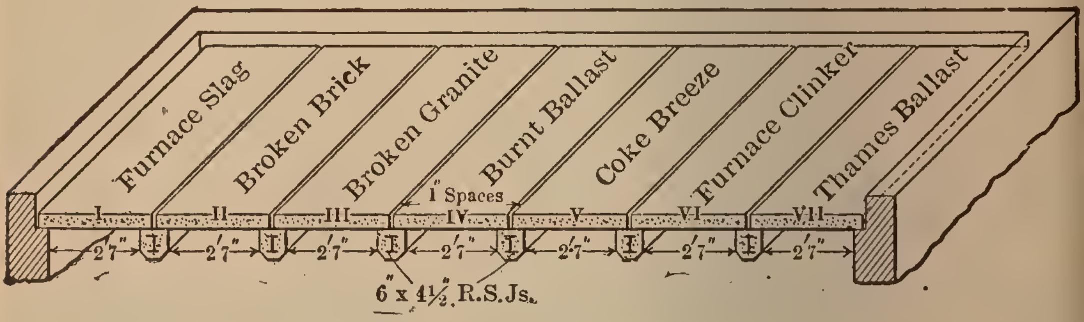


Fig. 133.—Diagram Showing Concrete Floor Composed of Bays of Different Compositions and Character of Aggregates.

Broken brick, or terra-cotta, furnace slag, or vitrified clinkers, should be used for the aggregate of any concrete to be termed strictly fire-proof. Broken stone or gravel is often used as an aggregate in concrete fireproofing, but unless it is of a stone little effected by heat, the concrete will not withstand the action of heat and water.

Limestone should never be used in concrete for fire-proofing.

During the year 1905 the British Fire-Prevention Committee made tests of various fire-proof concretes, as shown in Fig. 133.

The following is a description of the aggregates, giving

the amount of aggregate to one part by volume of cement in each case: *

"1. Furnace-slag Concrete. Bay No. 1.—Blast-furnace slag from the Islip Ironworks, Thrapston, Northampton, broken to pass a 1½-in. ring, three parts. Clean pit sand from Kent, two parts.

"2. Broken Brick Concrete. Bay No. 2.—Broken brick to pass a 1½-in. ring, three parts. Clean pit sand from Kent, two parts.

"3. Broken Granite Concrete. Bay No. 3.—Broken granite, ¾-in. (Guernsey granite chips), three parts. Clean pit sand from Kent, two parts.

"4. Burnt Ballast Concrete. Bay No. 4.—Burnt ballast, viz., clay from the neighborhood of Child's Hill, burnt with slack coal, broken to pass a 1½-in. ring, five parts.

"5. Coke Breeze Concrete. Bay No. 5.—Coke breeze broken to pass a 1½-in. ring (free from fine dust), from the retorts of a London gas company, five parts.

"6. Clinker Concrete. Bay No. 6.—Furnace clinker, viz., the raking from the furnaces of large boilers, broken as last three parts. Clean pit sand from Kent, two parts.

"7. Thames Ballast Concrete. Bay No. 7. (South Bay).—Thames ballast dredged from the River Thames to pass a 1½-in. ring, three parts. Clean pit sand from Kent, two parts.

"The object of this test was to determine the effect of fire on a floor composed of seven equal bays of concrete identical in all respects, except in the character of the aggregate and the composition of the concrete mixture. The fire was to last three hours, with a temperature reaching 1800° F., but not exceeding 2200° F., and was to be followed by the application of a hose stream under 60 lbs. pressure through a ½-in. nozzle to the underside of the floor for a period of two minutes. Previous to the fire test the top of the floor was to be loaded with a weight of 224 lbs. per square foot.

"The following is a log of the test. The table shows the temperature taken from the four pyrometer points, Nos. 5, 8, 9, and 10:

"At 2 p.m. the gas was lighted; from 2.10 p.m. onward the plastering fell off the beams in patches continuously through-

* Abstracts of Report on Experimental Fire Test made Oct. 24, 1905, by the British Fire-Prevention Committee, 1 Waterloo Place, Pall Mall, London, England.

out the test, but nothing occurred to record with regard to the bays; at 5 p.m. the gas was turned off. At 5.3 p.m. water was applied for three minutes at about 65 lbs. pressure through two branches (one through each of the door openings on the east side) each with a ½-in. nozzle. The effect of this was to wash more of the plastering off the beams, but nothing further could be observed. At 5.6 p.m. the water was turned off.

"During the test it was observed that the edges of the slabs Nos. 1, 4, and 7 were red hot; this was seen from above in the cavity between the edge of the slabs and the wall.

"OBSERVATIONS AFTER TEST.

"On Oct. 25 the bricks forming the load were partly removed and the whole were removed on Oct. 26. On Oct. 25 observations as to the state of the underside of the beams and slabs were made, and on Oct. 27 observations as to the state of top.

"Bay No. 1. Slag Concrete.—Soffit.—Practically flat on the underside; slight cracks visible corresponding to those on top.

"Top.—Slab cracked across in two places into about three equal parts, curved downwards about ¼-in. in the width.

"Bay No. 2. Broken Brick Concrete.—Soffit.—Curved downwards ¼-in. in the centre, in the width; slight cracks visible corresponding with those on top.

"Top.—Slab cracked across in three places into four rather unequal parts, the west-end portion of the slab being the largest very slight curve downwards.

"Bay No. 3. Granite Concrete.—Soffit.—Curved downwards ½ in. in the centre, in the width. About 1 in. washed off the surface in one part and slightly more or less all over the area struck by the water.

"Top.—Slab cracked across in three places, into four parts, the west-end portion being the largest, curved downwards about ½ in. in the width.

"Bay No. 4. Burnt Ballast Concrete.—Soffit.—Roughly curved downwards about ¼ in. in the centre in the width. About 3 ins. in depth washed off the surface in one part, along the third beam from the north, the greatest depth being about 3 ft. from the west side of the hut.

"Top.—No cracks—not curved.

"Bay No. 5. Coke Breeze Concrete.—Soffit.—Flat on the underside. About 1 in. washed off the surface, generally all over, more or less where struck by the water.

"TABLE OF TEMPERATURES TAKEN FROM POINTS NOS. 5, 8, 9, 10.

Time. P.M.	No. 5. Deg. F.	No. 8. Deg. F.	No. 9. Deg. F.	No. 10. Deg. F.	Mins. Elapsed.
2.5	900	900	920	840	5
2.10	1020	1010	990	1005	10
2.15	1105	1050	1040	1160	15
	(596.1)	(565.5)	(560.0)	(626.6)	
2.20	1040	1050	1030	1100	20
2.25	950	980	990	1000	25
2.30	1020	1040	1060	1040	30
	(548.8)	(560.0)	(571.1)	(560.0)	
2.35	1050	1100	1150	1100	35
2.40	1180	1220	1210	1200	40
2.45	1200	1310	1320	1280	45
	(548.8)	(710.9)	(715.5)	(693.3)	
2.50	1300	1400	1380	1380	50
2.55	1280	1350	1380	1360	55
3.0	1300	1450	1420	1360	60
	(704.4)	(787.7)	(771.1)	(737.7)	
3.5	1350	1440	1500	1420	65
3.10	1310	1405	1450	1400	70
3.15	1320	1440	1460	1410	75
	(715.5)	(782.2)	(793.3)	(765.5)	
3.20	1360	1450	1500	1440	80
3.25	1420	1540	1520	1500	85
3.30	1420	1560	1600	1550	90
	(771.1)	(848.8)	(871.1)	(843.3)	
3.35	1380	1450	1520	1600	95
3.40	1520	1600	1610	1600	100
3.45	1540	1620	1640	1600	105
	(837.7)	(882.2)	(893.3)	(871.1)	
3.50	1560	1600	1640	1600	110
3.55	1580	1620	1620	1610	115
4.0	1580	1630	1680	1660	120
	(800.0)	(887.7)	(915.5)	(904.4)	
4.5	1560	1600	1670	1700	125
4.10	1610	1700	1740	1720	130
4.15	1680	1720	1780	1760	135
	(915.5)	(937.7)	(971.1)	(960,0)	
4.20	1700	1720	1800	1780	140
4.25	1700	1760	1800	1810	145
4.30	1700	1780	1850	1820	150
	(926.6)	(971.1)	(1010.0)	(993.3)	
4.35	1740	1800	1860	1840	155
4.40	1730	1800	1880	1880	160
4.45	1780	1800	1880	1880	165
	(971.1)	(982.2)	(1026.6)	(1026.6)	
4.50	1760	1840	1900	1900	170
4.55	1780	1850	1900	1910	175
5.0	1780	1850	1910	1920	180
	(971.1)	(1010.0)	(1043.3)	(1048.8)	

Degrees in parentheses are Centigrade.

"Top.—No cracks—not curved.

"Bay No. 6. Clinker Concrete.—Soffit.—Flat on the underside.

"Surface pitted in places about 1 in. deep where struck by the water and in one place 2 ins. deep; one slight crack visible.

"Top.—Slab cracked across in two places into about three

equal parts, the west-end portion of the slab being the largest, curved downwards about $\frac{3}{8}$ in.

"Bay No. 7. Thames Ballast Concrete.—Soffit.—Curved downwards $1\frac{1}{2}$ ins. in the centre in the width. Several bad cracks longitudinally in the slabs, extending over almost the whole area, worst about the centre, the cracks being in various irregular directions. Surface damaged all over more than any of the other slabs, greatest depth about 2 ins. and a hole in the northwest corner through which daylight was seen.

"Top.—Slab cracked in very many places, cracks being generally transverse or across the slab, but in various diagonal directions as well, no actual longitudinal cracks on upper surface, which are so very marked on the underside, curved downwards about 2 ins. in the width.

"*Beams*—Portions of the plaster remain on all the beams, but it is badly cracked and flaked. Each beam has part of the concrete washed off where struck by water. No steel work is exposed. The concrete is disintegrated about 1 in. in depth, on the soffit of each, in patches."

Tests made by Ira H. Woolson show that concrete with a trap-rock aggregate is very little affected by fire until a temperature of 750° is reached, while with a limestone aggregate, a temperature of 500° caused a great loss in strength.

Tests made by the author show the following results, with concrete fire-proofing of different aggregates:

Cinder concrete, as ordinarily used, cinders not cleaned, mixed 1:3:5 and heated to a dull * red, showed a loss in weight after heating of 7 per cent, showing that a certain amount of the aggregate had been consumed. After being sprinkled with water and cooled, the concrete could be broken and crushed very easily.

Fine cinder screenings, such as are screened out of cinders when cleaned, and which is sometimes used as a filling between floor strips. Mixed 1:3:5 and heated to a dull red showed a loss in weight of 10 per cent, and after cooling could be crushed like poor lime mortar.

Cinders composed of 60 per cent vitrified clinkers, mixed as above, and heated to a dull red and cooled, lost about 1 per cent and very little strength.

Cinders composed of nearly all clinkers and mixed as above

* This is equal to about 800° F.

showed hardly any loss in weight or strength after being heated to a dull red.

Concrete made with crushed slag aggregate, mixed 1:3:5, showed hardly any loss in weight or strength, after being heated to a dull red and then cooled.

Concrete made with trap rock aggregate showed hardly any loss in weight, but after sprinkling with water and cooling, could be broken easier than before heating.

The result of all tests show that if a strictly fire-proof or fire-resisting concrete is desired it must be made with an aggregate that is not in any way affected by fire, or by being cooled with water.

The National Board of Fire Underwriters has recommended a "Building Code" from which the following excerpt is taken:

Reinforced concrete construction may be accepted for fire-proof buildings, if designed as hereinafter prescribed; provided, that the aggregate for such concrete shall be hard-burned broken bricks, or terra-cotta, clean furnace clinkers, entirely free of combustible matter, clean broken stone or furnace slag, or clean gravel, together with clean siliceous sand, if sand is required to produce a close and dense mixture; and, provided further, that the minimum thickness of concrete surrounding and reinforcing members $\frac{1}{4}$ in. or less in diameter shall be 1 in.; and for members heavier than $\frac{1}{4}$ in. the minimum thickness of protecting concrete shall be four diameters, taking that diameter, in the event of bars of other than circular cross-section, which lies in the direction in which the thickness of the concrete is measured; but no protecting concrete need be more than 4 ins. thick for bars of any size; and provided further, that all columns and girders of reinforced concrete shall have at least 1 inch of material on all exposed surfaces over and above that required for structural purposes; and all beams and floor slabs shall have at least $\frac{3}{4}$ in. of such surplus material for fire-resisting purposes; but this shall not be construed as increasing the total thickness of protecting concrete as herein specified.

All the requirements herein specified for protection of steel and for fire-resisting purposes shall apply to reinforced concrete filling between rolled-steel beams, as well as to reinforced concrete. Any concrete structure or the floor filling in same reinforced or otherwise, which may be erected on a permanent centering of sheet metal, of metal lathing and curved bars, or

a metal centering of any other form, must be strong enough to carry its loads without assistance from the centering, unless the concrete is so applied as to protect the centering as herein specified for metal reinforcement.

Exposed metal centering or exposed metal of any kind will not be considered as a factor in the strength of any part of any concrete structure, and a plaster finish applied over the metal shall not be deemed sufficient proteotion.

All concrete for reinforced concrete construction whenever used in such buildings must be mixed in a machine which mixes one complete batch at a time, and entirely discharges it before another is introduced. At least 25 complete revolutions must be made at such a rate as to turn the concrete over at least once in each revolution for each batch.

Before permission to erect any concrete-steel structure is issued, complete drawings and specifications shall be filed with the Commissioner of Buildings, showing all details of the construction, the size and position of all reinforcing rods, stirrups, etc., and giving the composition of the concrete.

The execution of work shall be performed by workmen under the direct supervision of a competent foreman or superintendent.

The concrete shall be mixed in the proportions of 1 of cement, 2 of sand, and 4 of other aggregates as before provided; or the proportions may be such that the resistance of the concrete to crushing shall not be less than 2000 lbs. per sq. in. after hardening for 28 days; but for reinforced or plain concrete columns the mixture shall not be leaner than 1 part of cement, 2 of sand, and 5 of the coarser aggregate in any case. The tests to determine this value must be made under the direction of the Commissioner of Buildings. The concrete used in concrete-steel construction must be what is usually known as a "wet" mixture.

Only high-grade Portland cements shall be permitted in reinforced concrete or concrete-steel constructed buildings. Such cements, when tested neat, shall, after one day in air, develop a tensile strength of at least 300 lbs. per sq. in.; and after one day in air and six days in water shall develop a tensile strength of at least 500 lbs.; and after one day in air and 27 days in water shall develop a tensile strength of at least 600 lbs. Other tests, as to fitness, constancy or volume, etc., made in accordance with the standard method prescribed by

the American Society of Civil Engineers, may, from time to time, be prescribed by the Commissioner of Buildings.

The sand to be used must be clean, sharp grit sand, free from loam or dirt, and shall not be finer than the standard sample kept in the Department of Buildings.

The stone used in the concrete shall be a clean, broken stone, of a size that will pass through a $\frac{3}{4}$ in. ring, or good gravel may be used in the same proportion as broken stone, or broken hard bricks, or terra-cotta, or furnace slag, or hard clean clinkers may be used.

Refractory Concrete.—This is a composition on which a United States patent has recently been allowed. It is a compound of carbon and incompletely reduced silica (two of the highest refractories) and Portland cement.

The carbon-silica compound is reduced in an electric furnace at a temperature of 6000° C.

The composition is worked the same as cement-concrete, wet, and poured or tamped into forms or to the desired shape, or as a lining for furnaces, kilns, etc., it can be used in the form of a plaster.

It can be used with any aggregate used in concrete and will render any concrete more or less refractory, depending on the quantity used.

Expansion and Contraction of Concrete.—Long walls of concrete if not reinforced should have expansion joints about every 30 feet. Ordinary concrete walls not reinforced will expand or contract as much as $\frac{1}{8}$ inch in 30 feet. If the concrete is well reinforced with iron it is not so liable to crack. Walls of reinforced concrete have been built two and three hundred feet in length with no joints, and which developed no cracks. Still it is best to make provision every 50 or 60 feet to take care of the expansion and contraction.

Concrete made rich in cement will contract or shrink more in drying than a poor mixture. Also a concrete made with fine sand will shrink more than if coarse sand had been used.

Porosity and Permeability of Mortar and Concrete.—*Porosity* is the property of materials for absorbing water.

Permeability is that property of concrete and other materials which permits water to pass through it.

To make mortar or concrete water-proof, enough cement must be used in the mixture to insure all the voids in the sand and aggregate being filled solid. This will require an excess

of cement over the exact bulk of the voids, as the cement may not be distributed uniformly throughout the concrete. If concrete the mixture should be mixed wet enough to "quake" when tamped into place, and it should be tamped and worked until all air bubbles are worked out.

The degree of waterproofness of concrete depends entirely on the denseness or solidity of the mass. For this reason a wet mixture is more waterproof than a dry mixture, as there are less voids and air bubbles.

If to each part of cement used there is used 10 per cent of lime putty, it will make a more nearly water-proof mixture than if no lime is used.

For mortar the following mixtures will be found nearly waterproof, and if when used for plastering it is given a troweling on the surface, it will make it more dense and waterproof.

Portland	cement,	1;	sand,	1.			
"	"	1;	"	2;	lime	putty,	½.
"	"	1;	"	3;	"	"	1.
"	"	1;	"	4;	"	"	1½.

A number of tests on the permeability of cement mortar under water pressure have been made by Jos. W. Ellms, chemist, Commissioner of Water Works, Cincinnati, Ohio, from which he made the following deductions:

1. No mortar is absolutely impervious to water if placed under sufficient pressure.

2. The permeability of a mortar decreases with age; and differences in the permeability of different mortars of approximately the same composition also largely disappears with age.

3. The permeability of mortars of approximately similar composition and made from the same grade of material, is probably more dependent on the compacting they receive when being placed than on almost any other factor.

4. The continuous filtration of water through mortar tends to decrease its permeability. Obviously this is not true if the water contains constituents which would produce disintegration of the cement, such as might be found in sea water, in water containing a large amount of carbon dioxide gas in solution, or in acid waters.

5. Mortars rich in cement are less permeable than mortars containing smaller proportions of cement to sand.

6. Mortars mixed dry are more permeable than those mixed

wet, but this difference diminishes the longer the dry mixture mortar is subjected to the continuous filtration of water.

7. The thoroughness with which the sand and cement are mixed and the extent to which the voids in the sand are filled by the cement, or in other words, the greater the density of the mortar, no matter how attained, the less permeable it becomes.

A solution of 1 pound of concentrated lye, 5 pounds of alum, and 2 gallons of water mixed with cement in the proportion of 1 pint of the solution to 5 pounds of cements and applied with a brush and well rubbed in will make cement walls waterproof.

The Puddling Effect of Water Flowing through Concrete.*—In the summer of 1904 Mr. W. R. Baldwin-Wiseman conducted a series of experiments on the rate of flow of water through a specimen of concrete, identical in composition with that used in the construction of the new graving-dock at Southampton. The experiments extended over a period of 50 days, readings being taken daily, or at more frequent intervals as occasion demanded, and an account of them has recently been published by the Institution of Civil Engineers.

The cylinder of concrete on which the experiments were conducted was 13 in. in diameter and 6 in. in thickness, and was made in a heavy wooden mould, on March 11, of Portland cement and crushed gravel ballast, gauged in the ratio of 1 to 4. The cement used was a normal chamber-kiln product giving the following tests: Residue on a 50×50-mesh sieve, 1.0 per cent; residue on a 76×76-mesh sieve, 4.0 per cent; setting time, 1 hour; tensile strength of briquettes made with 22 per cent of water and shaken into a mould without pressure, 450 lbs. per square inch after 7 days, and 600 lbs. per square inch after 28 days; specific gravity, 3.16. The ballast was obtained from the bed of the River Test; the stones were passed through a 1-in. ring, and both stones and gravel were of varying fineness, thus considerably reducing the percentage of voids.

The concrete had a specific gravity of 2.23, corresponding to a weight of 140 lbs. per cubic foot. It was removed from the wooden mould on May 18, and was fitted into a water-tight steel ring 13½ in. in internal diameter and 6 in. in height, forming part of the apparatus used in the experiments. In order to prevent side-flow best Swedish pitch was poured in small quantities, in a boiling condition, into the space between the

* *Engineering Record.*

concrete and the metal; and to obviate any tendency to leakage through the pitch, rings of best rubber, $\frac{3}{16}$ in. in thickness, 12 in. in diameter and 14 in. in external diameter, were placed above and below the test-block and between the block and the planed faces of the apparatus. The test-piece was fitted on a heavy cast-iron ring of exactly 12 in. in internal diameter, connected by bolts and nuts to a heavy cast-iron shallow reservoir above, accurately turned to an internal diameter of 12 in. and provided with a heavy flange, in which, as in the lower plate, was recessed a lip, slightly beveled inwards, thus insuring, with the rubber rings already referred to, an absolutely water-tight joint. The reservoir was surmounted by a heavy cast-iron stem recessed into it, and making with it an absolutely water-tight joint; at the upper end of this stem was an easily adjustable gland, consisting of a coil of rubber packings between two metal disks beveled internally, any water accumulating in the gland during an experiment being drawn off by a drip-tube. An accurately turned steel plunger working through this gland carried at its upper end a metal cap on which the loads were piled; and a pointer, rigidly attached just beneath the shoulder of the cap, slid over two fixed scales graduated in millimetre-divisions. The pressure on the upper face of the test-piece was recorded on a very sensitive Bourdon gauge fixed on a $\frac{1}{2}$-in. pipe, the centre of which was 1 in. above the upper face of the test-piece. The flow was measured by the descent of the piston, a drop of 1 millimetre being equivalent to a discharge of 6.205 cu. cm. of water, and the areas were so adjusted that a discharge of 1 cu. cm. per second was equivalent to a discharge of 1 imp. gal. per hour per square foot of test-piece exposed. The water used, which was taken from the corporation mains, was pumped from chalk, and was reduced from 18° to 6° of hardness, which was the hardness maintained throughout the experiments. The temperature of the air throughout the experiments varied between 12° and 15° C., but Mr. Baldwin-Wiseman did not introduce any correction for variation of the viscosity of the water with temperature, or for variation of the volume with pressure and temperature, as these did not appreciably affect the results.

It will be observed, on examination of the results on the experiments shown in Table 1, that, for a constant pressure of moderate magnitude, the flow at any time varies inversely as the time from the commencement of the experiments, but

TABLE 1.—TABLE SHOWING THE VARIATION IN THE AMOUNT OF WATER PERCOLATING THROUGH 6 INCHES THICKNESS OF PORTLAND CEMENT CONCRETE.

Days from Commencement.	Duration of the Experiment. h.	m.	s.	Pressure in Pounds per Sq. In.	Flow in Imp. Gallons per Hour per Sq. Ft. per Lb. of Pressure.	Per Cent of Flow in the First Experiment.
1	2	2	35	36	0.000398	100.0
1	0	7	25	36	0.000387	97.3
1	0	5	0	60	0.000345	86.7
1	0	9	0	60	0.000191	48.0
2	1	16	40	24	0.000197	49.5
2	9	35	55	24	0.000172	43.2
3	13	0	0	34	0.000125	31.4
4	25	9	0	34	0.000109	27.4
4	9	21	0	34	0.000087	21.0
5	18	40	0	40	0.000090	22.6
6	24	10	0	40	0.000075	18.8
7	16	56	0	40	0.000066	16.6
7	2	53	0	40	0.000060	15.1
22	26	39	0	32	0.000014	3.5
23	10	19	0	32	0.000012	3.0
31	26	46	0	31	0.0000083	2.1
32	28	59	0	31	0.0000077	1.9
36	71	18	0	31	0.0000070	1.8
38	48	7	0	31	0.0000050	1.5
42	69	50	0	30	0.0000049	1.2
44	24	25	0	48	0.0000088	2.2
45	21	35	0	48	0.0000066	1.7
46	25	15	0	48	0.0000028	0.7

with a sudden change of pressure there is a corresponding variation in the flow. Towards the conclusion of the experiments, small stalactitic growths appeared on the underside of the test-piece, and the percolation was so slow that no water fell into the drip-tin, the water being evaporated from the underside of the test-piece as quickly as it percolated through. The results of the experiments appear to show that, at or near the surface of the concrete, and under a moderately high pressure, the water dissolves out some of the material of the concrete, but under the reduced pressure which prevails in the small pores at some distance from the surface the dissolved material is precipitated on the sides of the pores, reducing the flow and eventually checking it.

Waterproofing Concrete.—*Sylvester Process.*—For waterproofing concrete surfaces that are subjected to slight or intermittent heads of water, the "Sylvester Process" has been used with success on some of the fortification works constructed by the government engineers. The method of mixing and applying was as follows: Thoroughly dissolve ¾ pound of

shaved Castile soap in 1 gallon of water, also dissolve ½ pound of powdered alum in 4 gallons of water. The walls should be dry and the soap applied first, at a boiling heat, being laid on with a flat brush, and not allowed to froth. After the soap wash has been on about twenty-four hours, and is thoroughly dry, the alum wash is applied in the same manner, being at a temperature of about 65°. This also should be allowed to dry for twenty-four hours before a second coat is put on. In a few cases one coat of each of the two mixtures have been sufficient; generally two or three coats of each are necessary to make the concrete impervious to water. The application of the process gives the concrete a uniform color and generally improves the appearance.

On floor work the mixture can be poured on and swept over the floor with a broom until the concrete has absorbed all it will.

Two brushes should be used, one for each solution.

*Water-proofing Basement Walls.**—It is extremely difficult to make a basement watertight by plastering on the inside surface, but not impossible. It can be done by thoroughly soaking the walls and sprinkling or painting with neat Portland cement and immediately applying a plastering composed of equal parts of cement and sand, using water-proof compound to the amount of about 2 per cent of the cement used. The neat cement will make a firm joint between the wall and plastering. The plaster must be applied immediately after the neat cement has been dusted or painted on. If the neat cement is used as a paint, it must be freshly mixed in small quantities every few minutes and followed by the plaster before it has set. Let the work be done in dry weather when no water is entering; or drain the work until the cement has a chance to set and harden.

Use of Concrete in Freezing Weather.—The use of concrete when the thermometer is below the freezing-point should be done with great precaution, if done at all.

The effect of freezing on Portland cement concrete is not so serious as it is on concretes made with natural cement, and when Portland cement concrete has been frozen and when thawed is given time to set hard and dry without freezing again, it will show little effects of being frozen. However, if

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* *Cement Age.*

it is frozen and thawed alternately several times, it will lose a great deal of its strength and may become worthless.

When putting in large masses of concrete it can usually be put in place and covered immediately to prevent it being frozen, but with small bodies of concrete, such as columns, beams, floor slabs, sidewalks, etc., they should not be put in place when the concrete is liable to be frozen before having set hard.

There are various methods used to prevent concrete from freezing, such as mixing salt in the concrete, mixing with hot water, warming with salamanders, steam, etc., but the only absolutely sure way to do a good and satisfactory job of concrete work, is to wait until warm weather comes. If salt is used to prevent freezing, the proportion to use is from 8 to 10 per cent of the weight of water used to mix the concrete.

Stable bedding and horse manure have often been used to protect concrete work and keep it from freezing. The heat from the manure will prevent the concrete from freezing, but the acids in the manure is liable to penetrate the surface of the concrete before the cement has set, and these acids will destroy the setting qualities of the cement and spoil the work. When stable bedding or manure is used the concrete should first be covered with about an inch of sand before the bedding or manure is spread. This sand will then prevent the bedding or manure from coming in contact with the cement and the sand will absorb the acids before they reach the cement.

Action of Cinder Concrete on Iron.—In several cases recently it has been found that iron which had been imbedded in cinder concrete had been badly eaten with rust or acids.

Small gas pipes laid in cinders in the Norwegian Hospital, Fourth Avenue and Forty-sixth Street, Brooklyn, N. Y., were found to be almost entirely destroyed. These pipes were $\frac{3}{8}$- and $\frac{1}{2}$-in. gas pipe laid about $1\frac{1}{2}$ ins. deep in the cinder fill about the girders. The pipes had to all appearance been destroyed by electrolysis, but tests failed to show any stray electric currents. Moreover, as all pipes except those laid in the cinder were intact, the destruction was doubtless due to the composition of the ashes, possibly to sulphuric acid contained in them.

Cinder concrete made rich with cement has very little, if any, effect on iron imbedded in it, as the cement overcomes the action of the acids in the cinders.

In cinder concrete made poor in cement, or which is subjected to being wet and drying alternately after being put in place, the action of the acids in the cinders will destroy the iron.

Thus all reinforcing to be used in cinder concrete should be galvanized or painted to prevent rusting.

Portland Cement Used Under Water.—When necessary to use Portland cement concrete or mortar for this purpose, the mixture must be protected from any disturbance whatever by the water when being put into place, and great care should be taken that the water in which it is afterwards submerged be still. If exposed to flowing water, either during or after depositing, the cement, the sand and the stone will invariably be separated.

Various methods are used to deposit concrete under water, as confining it in bags and putting into place the bags forming various shaped blocks of concrete when laid in place. Another method is to lower the bag, then open it, letting the concrete run into place.

A good method is to force the concrete down through a large pipe or tube, keeping the lower end of the pipe down to the deposited concrete. The pipe must be kept full of concrete and the weight of the concrete in the pipe will force it out below.

Buckets which open at the bottom are also used successfully in depositing concrete under water.

Effect of Oils on Concrete.—Concrete for engine beds or floors, where it will be liable to be subjected to oil drippings, or come in contact with oils in any manner should be thoroughly mixed and tamped into place so it will be one solid mass with no voids, and the exposed surface should be troweled to give it a finished surface through which the oil will not penetrate.

With a hard surface free from voids and given two or three months time to harden concrete will not be affected by oils, but if it is of a poor mixture or not given time to harden before coming in contact with the oil, the oil will penetrate into the concrete and cause it to disintegrate.

The following gives the result of tests of oil on cement mortar which was made at Cornell University, and which was described in a paper read by R. C. Carpenter,* Am. Soc. M. E., at the

* Professor of Experimental Engineering, Cornell University.

Annual Meeting of American Society for Testing Materials, Atlantic City, June 20–22, 1907, as follows:

"I have been unable to find any references to tests showing the effect of oil on concrete, although the question is often of considerable importance in connection with foundations for machinery. I find that the impression is frequently held among engineers that oil used in machinery is injurious to concrete foundations.

"In order to ascertain the effects of oil on concrete, Mr. Sawdon, an instructor in the Mechanical Laboratory of Sibley College, Cornell University, made the following investigations which, although not sufficient to fully decide the matter, will, I believe, throw some light on the question.

"The experiments were conducted by making briquettes of neat cement to which 2 per cent of oil was added in addition to the water. These briquettes were tested for tensile strength at the end of 24 hours, 7 days, and 28 days. As a basis of comparison, a test was also made of briquettes made from the same cement in the same manner without the addition of oil.

"Another series of tests was made on normal briquettes of neat cement which were kept in water 8 days, after which they were soaked in oil for 20 days. The table on page 202 give the results of the various tests,

"Considering the results of this experiment, it is noted that the effect of the oil when mixed with the cement is to materially retard the hardening process, and this is more marked with the linseed oil than with the engine oil. Even at the end of the 28-day period the briquettes mixed with 2 per cent oil were materially weaker than those without oil, although of sufficient strength to pass most specifications.

"The soaking of briquettes which were 8 days old, for 20 days in oil apparently had no material effect when linseed oil was employed and had a sensible weakening effect when engine oil was used.

"The results of the tests referred to are being supplemented by more extensive tests not yet completed. It will be noted in connection with these tests that adding 2 per cent of oil to the cement did not effect the soundness test."

Efflorescence on Concrete.—The white efflorescence sometimes seen defacing concrete is not permanent or serious, and is easily removed by scrubbing with broom and water. It is

TABLE I.—SOUNDNESS PATS—NEAT CEMENT.

No.	Treatment.	Test.	Results.
*.1	1 day in moist air.	Boiled 3 hours.	Sound
* 2	1 day in moist air.	8 days in linseed oil.	Sound
* 3	1 day in moist air.	8 days in engine oil.	Sound
† 4	1 day in moist air.	Boiled 3 hours.	Sound
‡ 5	1 day in moist air.	Boiled 3 hours.	Sound

* Without oil, 23 per cent water.
† 23 per cent of water, 2 per cent linseed oil.
‡ 23 per cent of water, 2 per cent engine oil.
All the pats adhered to the glass plate.

TABLE II.—TENSION TESTS OF CEMENT MORTAR IN OIL.

	Days in		Strength in Pounds per Square Inch.	
	Air.	Water.	Earth Test.	Average.
Neat cement, 23 per cent water, no oil. Allowed to set 24 hours in moist air	1	0	....	430
	1	6	753	696
	1	6	640	
	1	27	735	743
	1	27	751	
23 per cent water, 2 per cent linseed oil. Allowed to set 24 hours in moist air	1	0	190	180
	1	0	170	
	1	6	455	493
	1	6	532	
	1	27	618	572
	1	27	525	
23 per cent water, 2 per cent engine oil. Allowed to set 24 hours in moist air	1	0	320	332
	1	0	345	
	1	6	....	689
	1	27	....	696
Neat cement, 23 per cent water, no oil. Allowed to set 24 hours in moist air, 10 days in water and 8 days in oil	Linseed oil		....	720
	Engine oil		692	673
	Engine oil		655	

TABLE III.—SUMMARY OF RESULTS.

	Pounds per Square Inch. 24 Hours.	7 Days.	28 Days.
Neat cement, no oil	430	696	743
Mixed with 2 per cent linesed oil	180	493	572
Mixed with 2 per cent engine oil	332	687	696
Soaked after 8 days in engine oil	...	...	673
oSaked after 8 days in lincsed oil	...	...	720

caused by the wetting and drying of the concrete which leaches out the magnesium and calcium sulphates from the concrete.

Cements containing much sulphates of magnesium and calcium are more liable to show an efflorescence than those containing little of the above sulphates.

These sulphates are dissolved by water or dampness in the concrete and brought to the surface of the concrete where they

are deposited in a crystalline form. Thus this efflorescence usually appears after a long wet spell when the concrete has been exposed to much water or dampness.

The more nearly waterproof the concrete the less efflorescence will show on the surface.

When the surface of concrete is to be tooled over, if this tooling is not done until the water has leached to the surface the sulphates from the concrete, the tooling will remove permanently all the efflorescence.

Concrete to which salt has been added is very liable to show efflorescence.

Adhesion of Steel Rods and Concrete.—Various tests have been made by different engineers to obtain the adhesive power of steel rods bedded in concrete. Some of the tests showing as high as 700 pounds per square inch of surface of the rod, and about an average of 250 pounds per square inch.

This is for plain, round, or square rods, and should be considered as the limit of adhesion and used with a safety factor.

Deformed bars which form a mechanical bond with the concrete show a much greater strength of bond between the

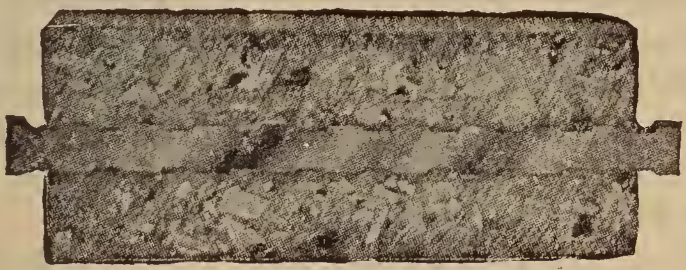

FIG. 134.—Mechanical Bond of "Johnson Bar."

rod and the concrete on account of the mechanical bond between the two. According to tests recently made at the engineering experiment station of the University of Illinois, little difference exists in the bond resistance per square inch of surface of the steel bar, whether the bar is imbedded 6 ins. or 12 ins. in the concrete, the average resistance due to adhesion being from 350 to 450 lbs. per square inch of contact surface of plain round steel bars. The adhesion in a rich 1:2:4 mixture of concrete is 10 to 15 per cent higher than in a 1:3:6 mixture. Flat bars show a lower resistance than round bars. The value of the adhesion depends upon the smoothness of the surface of the bar, the uniformity of its section and diameter, the adhesive strength of the concrete, and the shrinkage grip developed in setting. With cold-rolled shafting, smooth and

of uniform diameter, the adhesion is only about 147 lbs. per square inch of surface in contact with the concrete, while ordinary steel bars, having rough surfaces and varying in section and diameter, show an adhesion of about 400 lbs. With twisted or otherwise deformed bars anchored in the concrete throughout their length, very much higher resistances are developed.

Fig. 134 shows the mechanical bond between the "Johnson bar" and concrete.

Action of Sea Water on Concrete.—Concrete that is made so dense that the sea water cannot penetrate to its interior will withstand the effects of sea water; also on concrete that is under the water and is not alternately submerged and exposed to the air, waves, and tides, the salt water has little if any effect.

It has been noticed that sea walls above high tide and below low tide have been very little affected by the salt water, the line of effect or disintegration being between high and low tides, when the concrete is exposed to the action of the waves, and to being wet and dry alternately as the tides rise and fall.

Poor concrete or concrete containing voids through which the salt water can penetrate will in time decompose by the action of the salt water.

Cements that contain large amounts of lime and alumina are more readily attacked by the sea water than those that contain less lime and no alumina.

The Germans are now making a cement free from alumina, and which it is claimed withstands the action of sea water.

Puzzolan cements withstand the disintegrating effects of sea water better than other cements.

After a number of tests and studies of the action of salt water on various cements, Henri Le Chatelier, Paris, prepared and presented before the International Association for Testing Materials a paper in which he arrived at the following conclusions:

The most important conclusions from a chemical point of view, regarding the decomposition of hydraulic cements when exposed to sea water, are the following:

1. All the active ingredients in cements—lime, aluminates, and silicates—are decomposed immediately they come into direct contact with the magnesium salts of sea water, yielding soluble chlorides and sulphates of calcium, and so bringing all the lime present into a state of solution.

2. When the calcium sulphate found in natural waters or formed by the interaction of magnesium sulphate and the calcium compounds of cement reacts with calcium aluminate, it produces a calcium sulph-aluminate whose crystallization gives rise to swelling and cracking in the material. The action resembles that consequent upon the hydration of quicklime, but is much slower.

3. Penetration of marine salts takes place in two different ways; sea water penetrates en masse through all the flaws in the points of the masonry and through the crevices in the stones and bricks themselves. Most of these flaws in workmanship are unavoidable. From the present aspect, the normal porosity of cement plays only a secondary part in the process. Afterwards, when the cement is sound, circulation of and attack by sea water occurs almost exclusively by a process of diffusion, being the more rapid as the normal porosity of the cement is the greater.

4. All the phenomena of decomposition in sea water are at the mercy of a superficial film of extreme tenuity, whose impermeability tends to prevent, or rather to hinder, diffusive action, but whose expansion, caused by the formation of calcium sulph-aluminate, promotes swelling of the material and cracks through which the salt water soon penetrates in quantity.

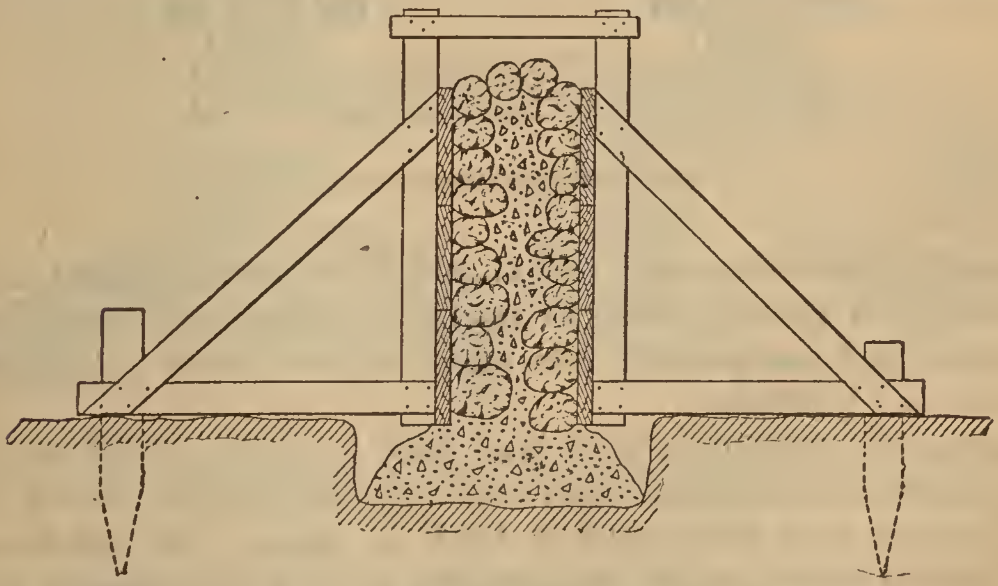

FIG. 135.—Form for Building Boulder or "Niggerhead" Wall.

Boulder-faced Walls.—A novel and very nice appearing wall for fence, garden, or retaining walls is made, as shown by Fig. 135, using field boulders or "nigger-heads" for the face of the wall as shown, and filling in with concrete.

The boulders are set against the wood forms and the interior filled with concrete, several boulders being put in place, then the space filled with the concrete.

After the concrete is hard enough, the forms are taken down and the boulders scrubbed off and the joints neatly pointed.

Concrete Cisterns.—Fig. 136 shows a method of constructing a concrete cistern. The circular forms are built as shown, the side ribs being formed of two pieces nailed together.

The concrete bottom is first put in place, after which the forms are set, and the concrete for the walls deposited. The con-

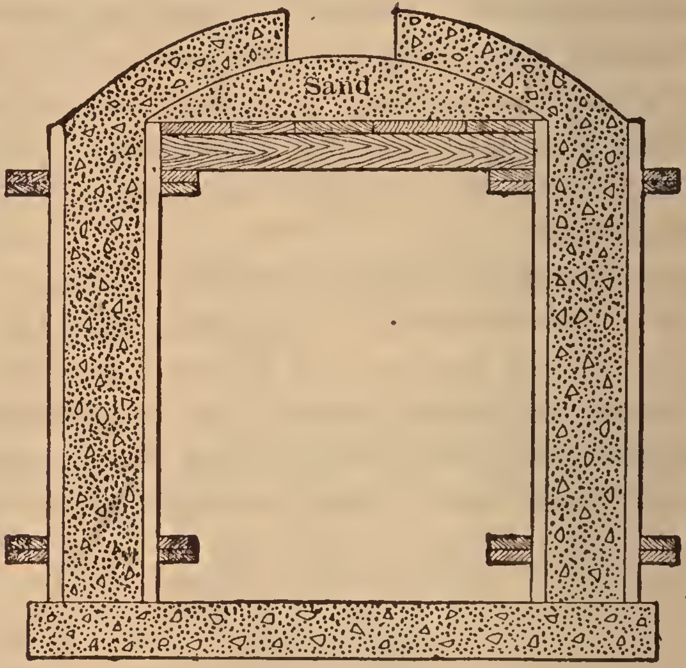

Fig. 136.—Cistern Forms.

crete for the bottom and wall should be rich with cement and mixed with enough water to render it mushy. It should be well tamped and puddled into place, so as to work out all air spaces and bubbles.

After the side forms have been filled in build a platform in the cistern, and on this platform shape the top or crown of the cistern with damp sand or earth, as shown. On this form of sand or earth deposit the concrete, leaving a manhole in the top, as desired.

After the concrete is hard the sand or earth can be taken out and the forms all removed. The inside of wall and bottom should then be given a coat of strong cement plaster to which has been added a little lime putty. The top of the cistern

should be plastered on the outside to prevent any surface water from penetrating.

In firm and solid clay the author has built cisterns, as shown by Fig. 137; the clay being cut out to the desired shape and

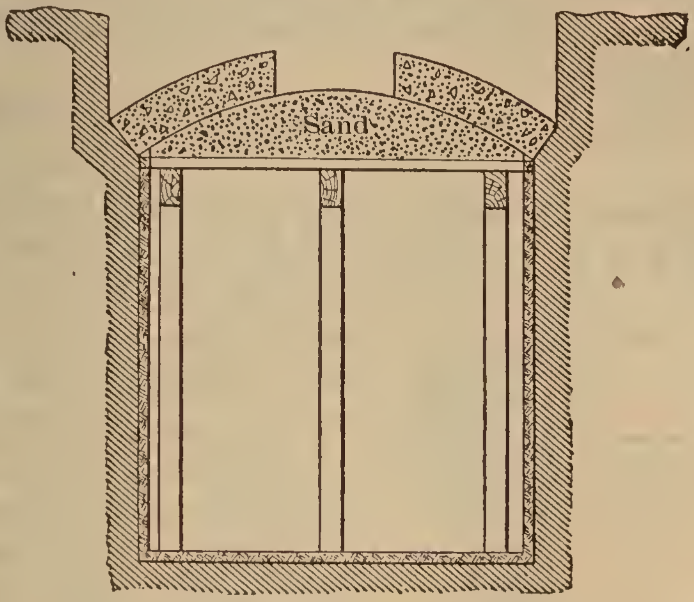

FIG. 137.—Form for Arch of Cistern.

size as shown. A shoulder is cut on the walls, as shown, upon which the top rests. The top is put in place, as previously described, and after the forms are removed, the wall and bottom

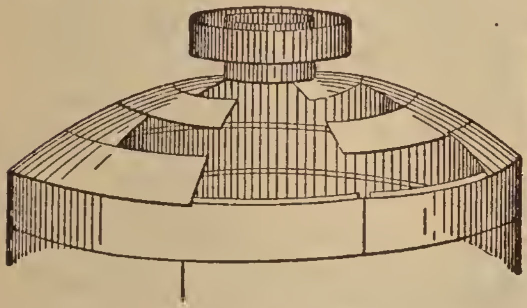

FIG. 138.—Dome Section of Metal Cistern Forms.

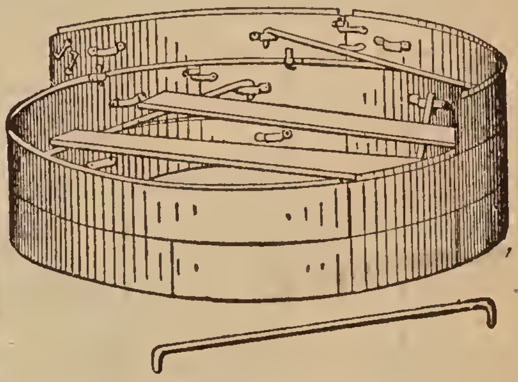

FIG. 139.—Sheet-metal Cistern Forms showing Brace and Scaffold Rods.

is plastered directly on the clay with cement mortar to a thickness of 2 inches.

Cisterns of this kind which the author built in 1886, are as good to-day as when built.

Metal forms are now on the market for making concrete cisterns, as shown by Figs. 138 and 139.

Concrete Chimneys.—Concrete chimneys can be built with perfect safety, the best chimney being made with an aggregate of clinkers or slag.

The chimney can be cast in forms or built up of blocks. When cast in forms it is well to reinforce it with several rods running from top to bottom, and also horizontal rods running around it at intervals.

Concrete chimneys should not be put to use until perfectly dry.

Cement Chimney Caps.—Cement chimney caps can be cast either in place or in moulds on the ground, and then set same as a stone cap. To cast the caps in place put a form around the chimney top, as shown by Fig. 140, making the member *A* the thickness desired for the projection of the cap over the brickwork. After the member *A* is put in place put on the member *B*, making the depth that desired for the thickness of the cap. Make a box or inside form, as *C*, the size of the flue, place it in position, and fill in around with the concrete as shown. After the concrete has set sufficiently remove the forms and trowel smooth.

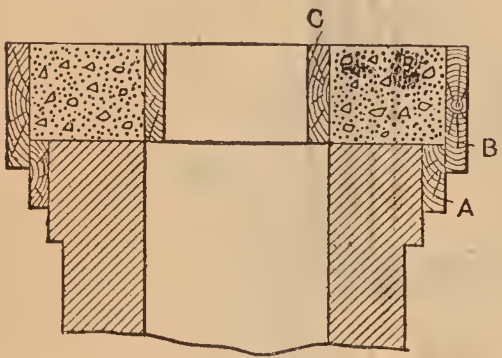

Fig. 140.—Forms for Building Concrete Chimney Caps.

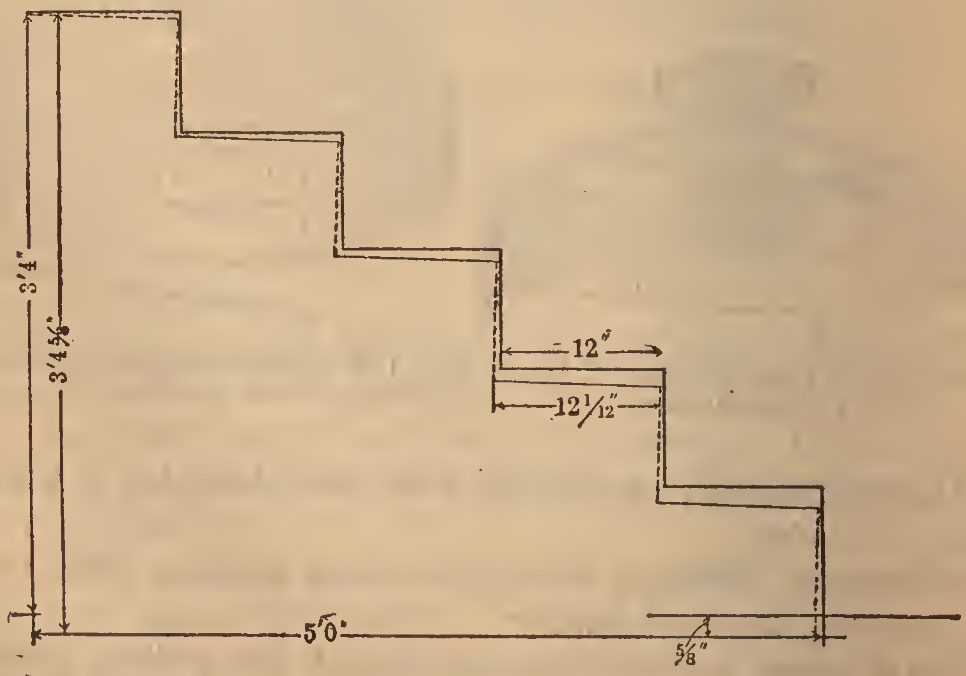

Fig. 141*a*.—Laying Out Correct Rise and Run of Steps.

Setting-stone or Concrete Steps.—Fig. 141*a* shows the rise and run of a flight of five steps, having a 12-inch tread and 8-inch rise. If the steps are cut square and set level the total rise would be 3 feet 4 inches and the total run 5 feet, but as it is customary to give the the treads of steps a droop or fall of about $\frac{1}{8}$ inch, it adds $\frac{1}{8}$ inch to the rise of each step and would make the total rise 3 feet $4\frac{5}{8}$ inches. The solid lines in the cut represent the steps set level and the dotted lines show set with a fall.

When the steps are cut square and set with a fall it throws the face of the step $\frac{1}{12}$ inch out of plumb, and if the steps are then set to show 12-inch tread we lose $\frac{1}{12}$ inch in the run of each step and the run of the five steps would be reduced to 4 feet $11\frac{7}{12}$ inches.

To keep the run 5 feet the steps should be set to show $12\frac{1}{12}$ inches on the tread, as shown, and to keep the total rise to 8 inches per step the steps must be set to show $7\frac{7}{8}$ inches rise on the face of the step.

Cement Brick.—Every manufacturer of cement blocks should have a brick machine in his shop, especially if the location is such that there are no clay brick kilns near, and the price of clay brick is high.

Cement brick are coming more into use and demand every day, and the block manufacturer who also runs a cement-brick machine can manufacture bricks at odd times when the block business may be slack and thus keep a stock of bricks on hand for sale, and at the end of the year the sales of cement brick will help swell the profits of the business.

Using a mixture of 1 cement and 5 of sand, a yard of sand and $6\frac{1}{2}$ bags (about $1\frac{2}{3}$ barrels) of cement will make about 1000 bricks, and four or five men should turn out from 12,000 to 15,000 bricks per day.

Sand-lime Brick.—Sand-lime brick are made by mixing about 95 per cent of sand and 5 per cent of lime together. The sand should be fine enough and the lime ground fine enough to pass a 20-mesh sieve. The sand and lime are mixed with a small amount of water and then pressed into moulds. After the moulded brick is taken from the moulds it is loaded on a car which when loaded is run into a cylinder or retort, which is then closed and a steam pressure of about 125 pounds is turned on and kept at this pressure for ten or twelve hours, when the bricks are taken out ready for use.

Fence Posts.—There are several makes of iron moulds for casting cement or concrete fence posts now on the market, and which give good satisfaction, but for the ordinary square

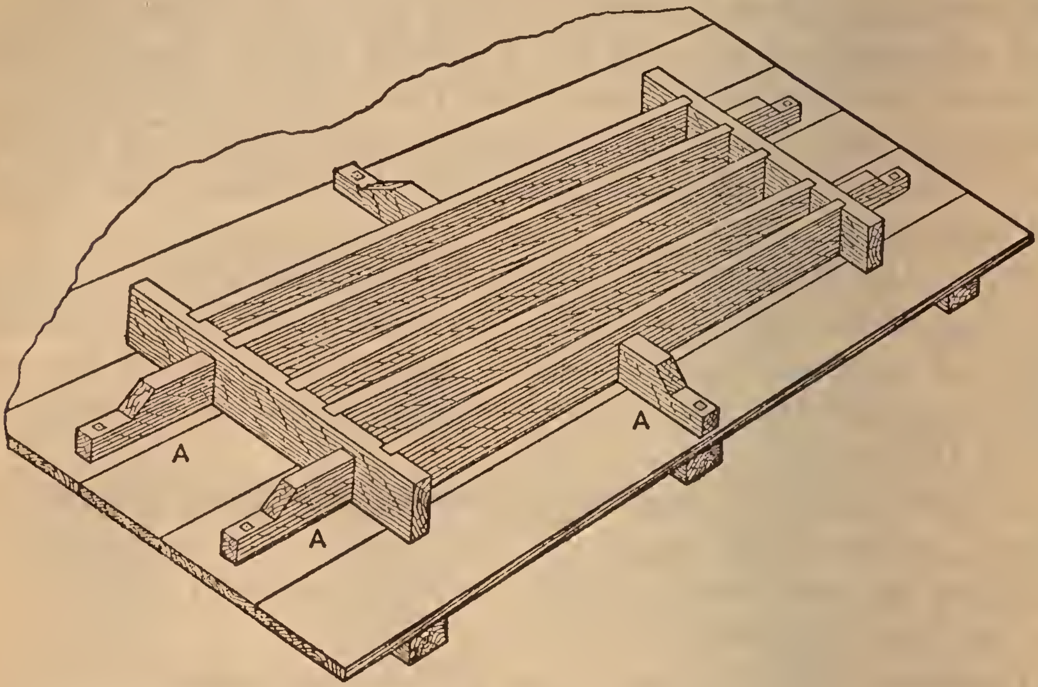

Fig. 141.—Moulds for making Fence Posts.

tapering post, good forms can be made of wood, as shown by Figs. 141 and 142.

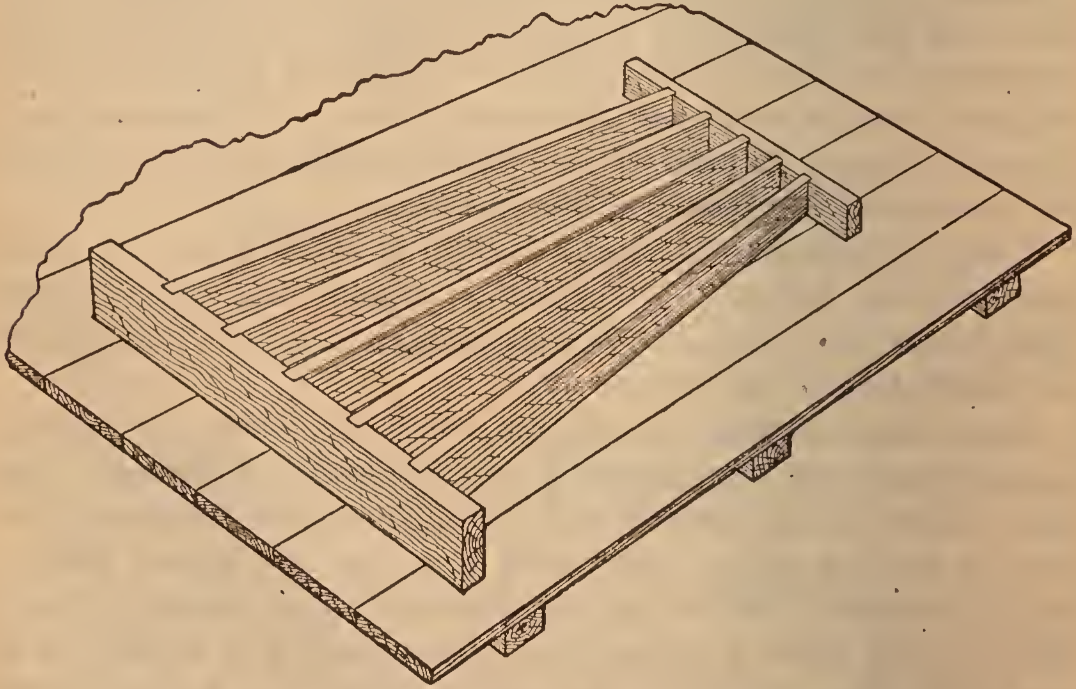

Fig. 142.—Moulds for making Fence Posts.

Fig. 141 shows a form for making four posts tapering on two sides only. The form is made with stay blocks, as

shown at *A*, fastened to the platform with a large screw or bolt. These stay blocks hold the forms in place. When the concrete is tamped in place and set these blocks are turned to one side, thus releasing the forms.

The four spaces should be filled with the concrete and tamped at the same time, so as not to spread or bulge the inside partitions of the forms.

Fig. 142 shows the same style of form, but made for posts tapering on all sides. Stay blocks are used, as explained for Fig. 141.

The post should be reinforced at each corner with a length

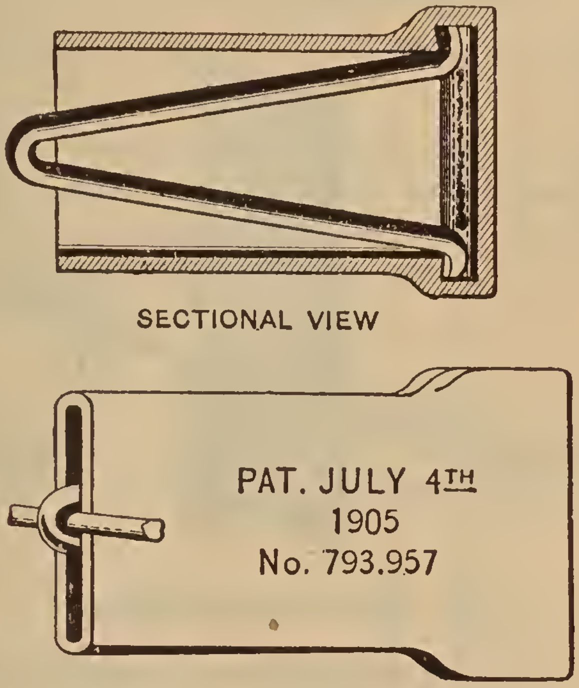

FIG 143.—Wire Fastening for Concrete Fence Posts.

of twisted fence wire. These wires should be imbedded in the concrete about ¾ inch from the surface at each corner.

Whatever device is to be used to fasten the fence wires must be inserted in the concrete before it sets. A good device of this kind is shown by Fig. 143, or a loop of galvanized wire with the ends turned or twisted and imbedded in the concrete, as shown by Fig. 144, makes a good fastening.

Owing to the small body of the post and the strength required, the concrete mixture for making posts should be pretty strong.

A good proportion is 1 part cement, 2½ parts sand, and 4 parts of broken stone or gravel to pass a ½-inch sieve.

The mixture should be used medium wet and enough forms should be used to allow the concrete to set before removing the forms.

Four bags (1 barrel) of cement, 8½ cubic feet of sand, and 14 cubic feet of stone or gravel mixed in the above proportions will make 13 posts 7 feet in length, 6×6 inches at the butt, and tapering to 3×6 inches at the top, or 14 posts 7 feet in length, 6×6 inches at the butt, and tapering to 4×4 inches at the top.

The post tapering to 3×6 inches is the stronger, as it is set with the parallel sides with the direction of the fence, thus

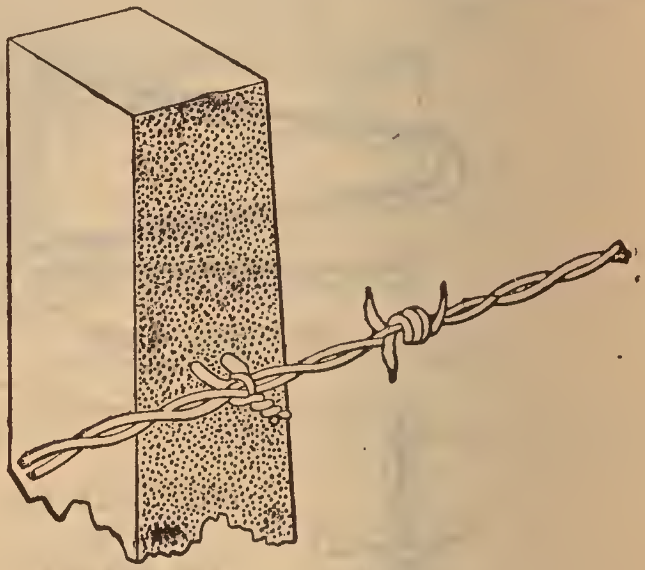

FIG. 144.—Staple Fastening.

throwing the thick way of the post to receive any shock likely to be given the fence.

The green posts should not be handled under 7 days and then very carefully, and should not be used in the ground under 6 weeks of age.

Troughs, Sinks, etc.—Watering troughs, etc., can very easily be made with concrete, using wooden forms or moulds. Fig. 145 shows a section and Fig. 146 a plan of a form for casting a trough.

As shown, the outside box or form is halved together at the angles and held in place by the stays or braces which are nailed to the platform. When the trough is cast these stays can be taken up, thus loosening the forms, which can readily be removed.

After the outer form is set up the concrete should be filled in to the thickness required for the bottom of the trough,

tamped solid, and leveled off to receive the inside form, which should then be put in place and the sides filled in with the concrete. If necessary, nail a couple of cleats across the top

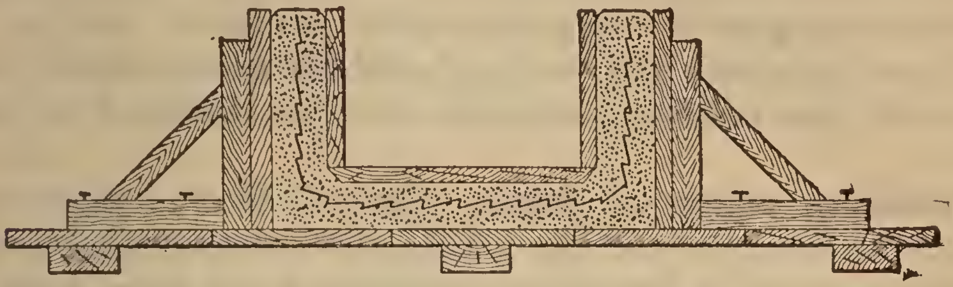

FIG. 145.—Section of Trough Mould.

of the form to hold the inside form down while tamping the concrete.

The inside form should be made as shown, and the cleats should be put on with screws, so they can be easily taken off, thus making it easy to remove the forms. The top edges of the trough can be rounded off as shown.

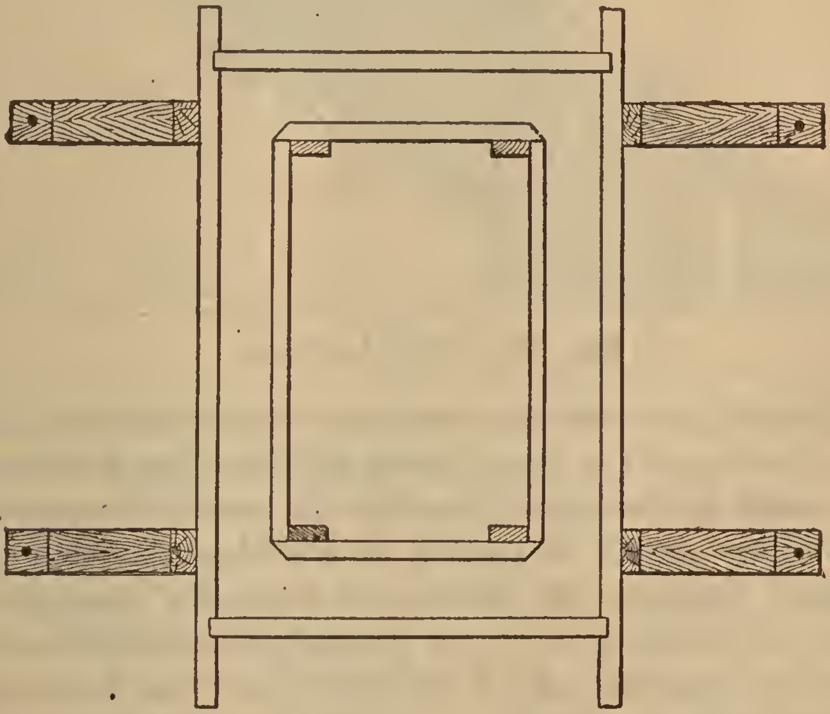

FIG. 146.—Plan of Trough Mould.

To reinforce the concrete expanded metal or woven wire should be put in as shown, on all sides and bottom.

The mixture for this sort of work should be used rather wet and should be worked into place, so as to break and remove all air pockets or spaces. It should be mixed 1 part cement,

2 parts sand, 3 parts small broken stone or gravel, and, to make the mixture more waterproof, a little lime putty should be added.

This putty should be made up several days before using, to insure every particle being thoroughly slaked.

When completed the trough should be given several coats of some waterproofing compound, such as described on page 197.

Concrete Stairs or Steps.—Fig. 147 shows how to construct the forms for building a flight of concrete stairs or steps. A plank should be set up on each side of the steps with the rise and tread of the steps laid out on it as shown. Planks

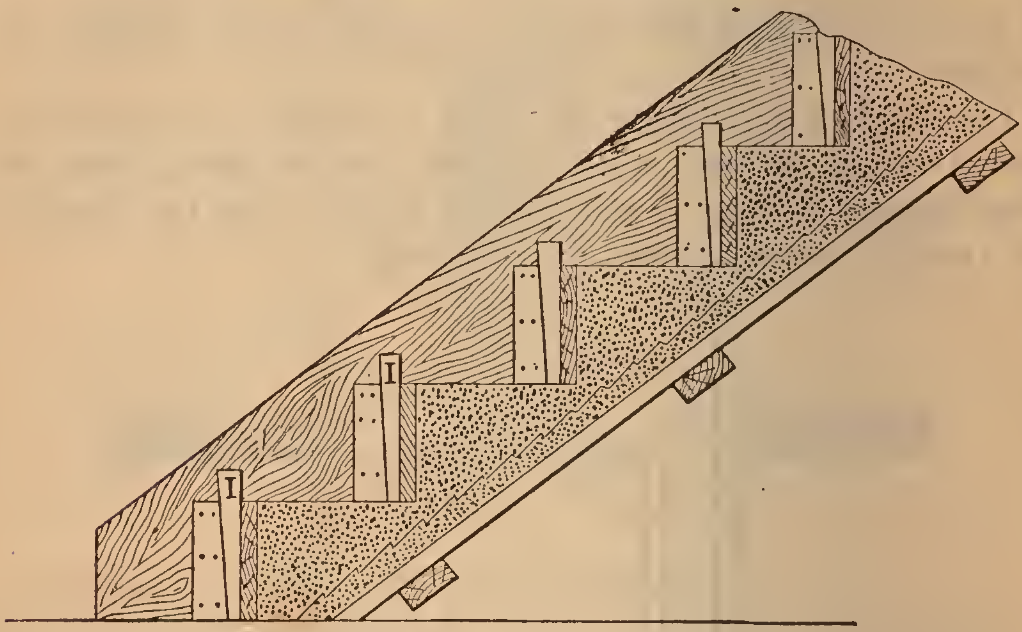

FIG. 147.—Form for Steps.

should then be cut between these two planks and put in place to form the rise of the steps, being held in place by cleats and wedges nailed on the plank, forming the side of the steps.

These cleats should be put on so a wedge, shown by *I*, can be inserted between the cleat and form for the rise. The object of this wedge is, so it can be easily removed, thus freeing the plank forming the rise of the steps, so it can be taken out.

When the steps are built up an embankment the earth can be graded off to suit the slope and the concrete deposited thereon, but for stairs in buildings or such places, a wood form must be erected, as shown, to carry and form the back or soffit of the stairs.

In such cases the stairs should be reinforced with expanded metal or some other suitable reinforcing as shown.

In depositing the concrete a coating of mortar should be kept against the plank forming the rise of the steps, and the tread should be given a top dressing about an inch in thickness.

The coarse concrete can be deposited and tamped solid, then the top dressing of the steps put in place, and the face forms removed and both the rise and tread of the steps troweled smooth.

On page 373 will be found a table giving the rise and tread of steps for various rises and runs.

When putting concrete in place around a beam, such as is shown by Fig. 18 on page 108, the soffit of the beam should be covered with a mortar mixture of cement and sand, thin enough so it will run under the beam and fill the space where

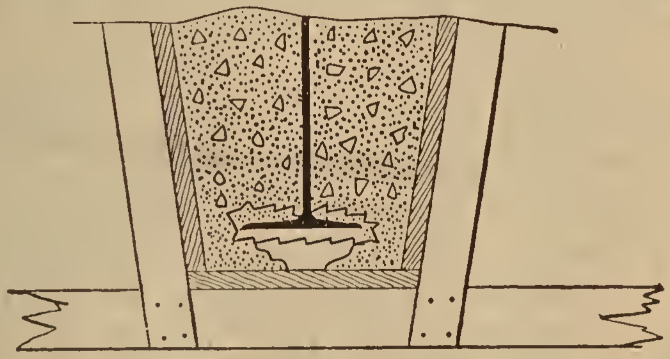

FIG. 148.—Cavity Caused by Poor Ramming or Puddling.

it would be difficult to force concrete made with a large aggregate.

The mortar should be forced through from one side until it appears on the opposite side of the beam. This will insure the space being filled with mortar.

If the mortar or concrete is put in on both sides simultaneously and rammed, the air under the beam will be confined and will cause a pocket or void in the concrete soffit of the beam, as shown by Fig. 148.

Drain Tile and Sewer Pipe.—The concrete for drain tile and sewer pipe should consist of 1 part of Portland cement with 3 to 5 parts of clean, sharp gravel, entirely free from voids, and containing no stone of more than ½ inch in diameter. If no gravel is procurable, well crushed stone, not exceeding ½ inch in diameter, mixed with sufficient sharp sand to fill all voids, may be substituted in about the same proportions. If neither crushed stone nor gravel is available the mixture

may consist of 1 part cement to 3 or 4 parts of clean, sharp sand. In preparing the mixture add only sufficient water to bring the mixture to the consistency of damp earth. The moulds should be filled as quickly as possible after the mixture is prepared and thoroughly tamped as they are being filled. The strength of the tile will depend not only upon the quality of the cement and the aggregate, but upon the thoroughness of the tamping as well. It is very necessary that the concrete be well set before the removal of the mould. The inner core may be compressed and withdrawn almost immediately after the filling of the mould, but the outer shell should stand in place for from one to two hours, according to the state of the weather, before removal. It is advantageous to have a few extra bottom rings, and in the event of building one size of tile only an extra outside shell will facilitate the work. In hot weather this tile should be made and kept well protected from the rays of the sun, and should be frequently sprinkled with water for a few days after being made to provide the necessary moisture to carry the hardening process to completion. The tile should stand for three weeks or a month before being put to use. If possible, it is better to make the tile one year for use the following year. If, however, it is necessary to use them shortly after they are manufactured they should be handled very carefully.

Laying of Drain Tile.—Judgment must be exercised in determining the necessary size of tile for road crossings. A great volume of water will be carried away by a 12-inch tile if properly laid, and if at the outlet end there is sufficient fall for the escaping water. In many cases, of course, it is necessary to use a larger tile than one 12 inches in diameter, but it is absolutely necessary that from 8 to 12 inches of well laid roadbed cover the tile to prevent injury from traffic, and on this account it is sometimes difficult to get the tile placed at the necessary draining level. Where the use of one very large tile would necessitate the raising of the road level to a great height in order that the tile may be properly protected, it is advisable to use two or more tiles of a small size, placed one or more feet apart, with the intervening earth very solidly packed between and around them. The appearance of a road culvert of this kind is very much enhanced by the construction of mouth-shaped Portland cement concrete abutments. It is most important that the bottom of the tile should be slightly

below the level of the feeding ditch, and that the tile be laid with a reasonable dip, and at the outlet end the greater the fall for the escaping water the better. Drain tile molds can be procured of the following diameters: 4, 6, 8, 10, 12, 15, 18, 24, 30, and 36 inches.

Plastering or Patching Old Concrete or Sidewalks.—To make a mortar for plastering on old concrete, patching sidewalks, etc., mix the mortar thoroughly, then let it stand for about an hour, or until the initial set takes place, then add about 5 per cent lime putty and remix until it is a plastic mass of a uniform color (the more mixing the better).

Wash the surface on which the mortar is to be applied with a solution of diluted muriatic acid, which takes out all the dirt and opens the pores of the old work, then wash with clean water. Apply the mortar, keeping the old work well wet, and as soon as the new plastering is in place, cover with burlap and keep wet for several days until thoroughly hard.

Plastering put on in this manner will not scale or peel off.

Dry Grouting Brick Pavements.—On a bed of about 6 inches of concrete spread about 1 inch of dry sand and cement, mixed 1 part cement to 2 parts sand. Level this off for a cushion and lay the bricks, keeping them apart about ¼ inch all round. After the bricks are set in place ram them to an even bearing by laying a plank on the bricks and ramming with a heavy hammer. After the bricks are rammed solid and level on top spread over and brush all the joints full of a dry mixture of equal parts of sand and cement, then sprinkle with as much water as the cement in the joints and cushion will absorb.

This manner of grouting leaves the top of the pavement clean and also leaves the filling of the joints a little below the top of the bricks, thus giving a rough surface for a foothold for horses.

When laying the bricks thin strips of wood or metal can be used in the joint to keep the courses of bricks apart. As soon as one course is laid the strip is taken out to use for the next course.

A Paint for Concrete—A wash or paint for concrete is made by mixing two parts of Portland cement with one part of marble dust to the consistency of cream and applying with a brush. The surface to which it is to be applied should be thoroughly wetted just before the paint is put on.

Non-freezing Cement.—Referring to non-freezing cement, *Le Beton Arme*, gives a number of methods of producing this material in cases of urgency, and where the cost of the work dose not make the use of the expedients too high.

First, the making of the mortar with hot water, which is stated to be quite efficacious.

Second, the addition of hydrochloric acid to the Portland cement; or,

Third, a solution saturated with soda is also given as a method of producing prompt setting and hardening at short periods.

An excellent mixture of this kind may be obtained by mixing one quart of cement and lime, three quarts of river sand and two quarts of water, containing in solution two pounds of soda.

The Effect of Frost on Cinder Concrete.*—In discussing a paper recently read before the Boston Society of Civil Engineers, Mr. J. R. Worcester gave some information as to the effect of frost on cinder concrete. He was called in as an expert to examine some concrete, which it was claimed was poorly applied in a piece of work done with expanded metal reinforcement. Upon examination, he recommended that the work should be torn out, but at the request of the contractor more time was allowed. After a couple of weeks of warm weather which dried the upper surface, the setting, which had been delayed by the frost, took place as naturally as it would if it had never been frozen, and when the final test was made it stood a load of 244 pounds per square inch.

Cement-milk Paint.—Stir into a gallon of skim-milk about 4 pounds of Portland cement. The skim-milk will hold the paint in suspension, but the cement being heavy, will sink to the bottom, so that it is necessary to keep the mixture well stirred with a paddle while using. Mix only enough at a time for one day's use. This paint becomes hard in about eight hours and is very durable.

It can be colored by the use of any paint powder. The addition of carbolic acid or any other disinfectant makes it very suitable for dairy work, chicken houses, etc.

Color of Concrete.—The color of concrete is always the same as the color of the materials when uniformly mixed dry; thus to know the color of finished seasoned (hardened) concrete,

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* *Cement Age.*

mix your materials identically as you intend to use them, and such, mixed before the addition of water, will be the color of the finished product.

Painting on Cement or Concrete.—Paint will not adhere to any cement work unless it is perfectly dry or seasoned. The caustic properties must become neutralized by age before the paint will adhere perfectly.

As this requires some time, the following receipt is given, which will accomplish the same result artificially:

Sponge the surface with a solution of 12 fluid ounces of oil of vitriol (sulphuric acid) in 1 gallon of soft water. This will neutralize any caustic lime that is present in the cemented surface and turn it into the inert sulphate of lime (gypsum). It also roughens the surface, giving the oil or paint a better grip, so that succeeding coats will obtain a firm hold. Then to neutralize the remaining traces of acid alkali, apply a wash of strong vinegar and allow the vinegar to dry thoroughly before applying the paint.

When the cement is a month or so old the dilute acid wash can be dispensed with and a solution of 4 ounces of bicarbonate of ammonia in 2 gallons of water used in its place, in which case the surface need not be rinsed with clear water, but may be painted upon as soon as it is dry. In order to exclude moisture the best plan is to prime the surface treated as above with good old raw linseed-oil, giving it ample time to become hard. Upon this coat of oil, which should be applied liberally to stop suction, a coat of flat paint, composed of the necessary pigments, linseed-oil, turpentine, and japan drier, should be given, and if this shows up unevenly another coat of the same paint and finally a finishing coat of weather-proof gloss paint or enamel, made of good pigments and exterior varnish. This treatment is certain to keep out moisture and is, of course, intended for concrete blocks that are not colored, but made in the natural color of cement. For colored concrete blocks, where it is desired to preserve the original color and which, as a matter of course, are not to be painted, one part of water glass (silicate of soda, concentrated) is to be mixed with three parts of rain water. When this is applied to the cemented surface it decomposes any lime that may be present and converts it into silicate, and while the color becomes somewhat darker the surface acquires a hardness which resists the action of the weather and keeps out moisture.

Painting with Cement Wash.—The following method of painting a cement wall was described at a recent convention of master painters. The building had become discolored in places, and the joints were of a different color from the surface of the blocks. Two parts of Portland cement were mixed with one part of marble dust and mixed with water to the consistency of thin paint or a thick whitewash. The wash was applied with ordinary whitewash or calcimine brushes, and a man kept busy playing a hose on it while the work was being done. The wall was well wetted before the application of this paint and kept constantly wet while the material was applied, and then kept up for a day longer, in order to make the cement wash adhere to the cement surface. The whole secret of success lay in keeping the wall constantly wet.

Water for Mixing Concrete.—The water for mixing concrete should be as clean as possible, and should contain no acids. Water which runs from coal mines should not be used for concrete work, as it usually contains free sulphuric acid, and iron sulphate, and is not fit for cement work.

Grades of Concrete.—Concrete can be divided into three grades, depending on the strength of the mixture, and the different grades can be used for the various purposes for which concrete is used, the grade to be used depending on the strength required and the use to which the concrete is to be put. The three grades may be known as first, second, and third class concrete. The proportions for first class concrete are 1:2:4, the aggregate to be hard trap, granite, or gneiss.

The proportions for second class concrete are 1:2½:5, and for third class are 1:3:6; the aggregate for the second or third class concrete may be a hard broken stone or gravel, as approved.

To Retard the Setting of Cement.—A small percentage of lime putty (about 5 per cent) will lengthen the time of setting of cement mortar. Or let the mortar take its initial set and then remix thoroughly. Mortar that has had its initial set and is retempered is twice as slow in setting as it was before.

Light-colored Cements.—The lightest colored cements are those manufactured in the Lehigh Valley, Pa., "Lehigh," "Dragoon," "Whitehall," etc.

A white Portland cement is also manufactured by the Art Portland Cement Co., Kimmel, Indiana.

To Remove Mortar Spots from Concrete Blocks.—To remove mortar spots from concrete blocks caused by being spotted with mortar when set, wash thoroughly with a solution of hydrochloric acid and water. After using the acid wash well with clean water to remove all acid.

Laying Floors for Concrete or Tile.—A wood floor upon which concrete or tile is to be laid should always be laid with open joints, say ¼ inch to boards 10 inches wide, or in like proportion, so that when the concrete is laid there will be no danger of the floor bulging up when the boards swell after the wet concrete is put upon them.

Removal of Forms.—The forms on some concrete work, such as small foundations, walls, etc., can be removed in two or three days, but on walls that extend to considerable height, columns, girders, floor slabs, etc., the forms must be left in place much longer. On ordinary floor work supported by I-beams, the centering, or forms, should be left in place at least ten days, and with work reinforced with rods, the forms should be left in place for at least 3 or 4 weeks, and, in some cases, especially in cold weather, they should be left in place longer. Nearly all the recent failures of concrete work have been the result of poor work and removing the forms too soon.

To Harden Concrete Surfaces.—The surface of concrete can be rendered much harder by the application of a wash of silicate of soda and potash mixed in about 10 parts of water. The wash fills all the pores of the concrete and renders it hard and waterproof.

The silicate of soda and potash is known as soluble glass or dissolved flint, and when mixed as a wash is called "water-glass."

The concrete should be free from all moisture before the wash is applied.

Use of Slag Cement.—A slag cement should not be used for any concrete work above the ground where it will be kept dry, as it is not durable unless exposed to moisture.

Water-proofing for Cement Blocks.—Shave ½ lb. castile soap into 1 gallon water; let it dissolve, but do not make suds. Apply it while boiling hot to the surface of the blocks, using a brush. After the soap wash dries apply a lukewarm solution of ½ lb. powdered alum in 4 gallons of water. Two coats of this mixture will close the pores and render the blocks waterproof.

Duodecimals are denominate fractions of a linear, square, or cubic foot, formed by successively dividing by 12.

Duodecimals are used chiefly in the measurement of lines, surfaces, and solids.

The *foot* is the *unit* of measure, and is divided into 12 equal parts, called *primes* ($'$); each prime, into 12 equal parts, called *seconds* ($''$); each second, into 12 *thirds* ($'''$); and each third, into 12 *fourths* ($''''$), etc. These marks used to denote the different denominations are called *Indices.*

TABLE OF UNITS.

$1'$ =			1/12	of a foot.
$1''$	= 1/12 of $1'$	= 1/12 of 1/12 of 1 ft.	= 1/144	of a foot.
$1'''$	= 1/12 of $1''$	= 1/12 of 1/144 of 1 ft.	= 1/1728	of a foot.
$1''''$	= 1/12 of $1'''$	= 1/12 of 1/1728 of 1 ft.	= 1/20736	of a foot.

Duodecimals are added and subtracted in the same manner as other Compound Denominate Numbers.

Multiplication of Duodecimals is similar to that of Compound Numbers.

The denomination of the product of two or more factors is indicated by the *sum* of their indices.

EXAMPLE.—Multiply 18 ft. $6'$ by 9 ft. $3'$.

EXPLANATION.—$6' \times 3' = 18'' = 1'\ 6''$. Write the $6''$ one place to the right, and add $1'$ to the next product. $18 \times 3' + 1' = 55' = 4$ ft. $7'$, which write in their order. Next, $9 \times 6' = 54' = 4$ ft. $6'$. Write the $6'$ in its place, and add the 4 to the next product. $18 \times 9 + 4 \surd 166$ ft. The sum of the partial products is 171 ft. $1'\ 6''$.

18 ft.	$6'$		
9 ft.	$3'$		
4 ft.	$7'$	$6''$	
166 ft.	$6'$		
171 ft.	$1'$	$6''$	

To Find the Cubical Contents of Floor Slabs.—To compute the cubical contents of concrete slabs or floors of various thicknesses, multiply the surface of the floor or slab by the following:

If concrete is

2	inches	thick	multiply	by	0.166	will	give	cubical	contents.
3	"	"	"	"	0.250	"	"	"	"
4	"	"	"	"	0.333	"	"	"	"
5	"	"	"	"	0.416	"	"	"	"
6	"	"	"	"	0.500	"	"	"	"
7	"	"	"	"	0.582	"	"	"	"
8	"	"	"	"	0.666	"	"	"	"

If concrete is

9	inches	thick	multiply	by	0.750	will	give	cubical	contents.
10	"	"	"	"	0.833	"	"	"	"
11	"	"	"	"	0.916	"	"	"	"
12	"	"	"	"	1.000	"	"	"	"
13	"	"	"	"	1.083	"	"	"	"
14	"	"	"	"	1.166	"	"	"	"
15	"	"	"	"	1.250	"	"	"	"
16	"	"	"	"	1.333	"	"	"	"
17	"	"	"	"	1.416	"	"	"	"
18	"	"	"	"	1.500	"	"	"	"
19	"	"	"	"	1.582	"	"	"	"
20	"	"	"	"	1.666	"	"	"	"
21	"	"	"	"	1.750	"	"	"	"
22	"	"	"	"	1.833	"	"	"	"
23	"	"	"	"	1.916	"	"	"	"
24	"	"	"	"	2.000	"	"	"	"

WHAT A BARREL OF PORTLAND CEMENT WILL DO.

A barrel of Portland cement weighs about 380 pounds net.

A barrel of Portland cement weighs about 400 pounds gross.

A barrel of Portland cement contains about 3.40 cu. ft. packed.

A barrel of Portland cement contains about 4.25 cu. ft. loose.

A barrel of Portland cement contains about 2.73 bushels packed.

A barrel of Portland cement contains about 3.61 bushels loose.

A barrel of Portland cement will make about 3.15 cu. ft. of neat mortar.

A barrel of Portland cement will make about 5.4 cu. ft. of mortar mixed 1 to 1.

A barrel of Portland cement will make about 8.5 cu. ft. of mortar mixed 1 to 2

A barrel of Portland cement will make about 10.7 cu. ft. of mortar mixed 1 to 3.

A barrel of Portland cement will make about 13.5 cu. ft. of mortar mixed 1 to 4.

A barrel of Portland cement will make about 23 cu. ft. of concrete mixed 1, 3, 5.

A barrel of Portland cement will make about 26 cu. ft. of concrete mixed 1, 3, 6.

A barrel of Portland cement will make about 29 cu. ft. of concrete mixed 1, 3, 7.

A barrel of Portland cement will make about 30 cu. ft. of concrete mixed 1, 3, 8.

A barrel of Portland cement (neat) will cover about 40 sq. ft. 1 in. thick.

A barrel of Portland cement to 1 sand will cover about 65 sq. ft. 1 in. thick.

A barrel of Portland cement to 2 sand will cover about 92 sq. ft. 1 in. thick.

A barrel of Portland cement to 3 sand will cover about 128 sq. ft. 1 in. thick.

A barrel of Portland cement to 2 sand will lay about 750 brick with $\frac{3}{8}$-in. joint.

A barrel of Portland cement to 2 sand will lay about 1050 brick with $\frac{1}{4}$-in. joint.

A barrel of Portland cement to 3 sand will lay about 900 brick with $\frac{3}{8}$-in. joint.

A barrel of Portland cement to 3 sand will lay about 1350 brick with $\frac{1}{4}$-in. joint.

A barrel of Portland cement to 3 sand will lay about 2 perches of rubble stonework.

Amount of Sidewalk per Barrel of Cement—1 barrel of cement will lay sidewalk as follows:

Base,	1–2–4,	$3\frac{1}{4}$	inches thick	37 square feet.
Top,	1–1,	$\frac{3}{4}$	inch thick	
Base,	1–2–4,	4	inches thick	30 square feet.
Top,	1–1,	1	inch thick	
Base,	1–2–4,	5	inches thick	24 square feet.
Top,	1–1,	1	inch thick	
Base,	1–3–5,	3	inches thick	35 square feet.
Top,	1–1,	1	inch thick	
Base,	1–3–5,	4	inches thick	32 square feet.
Top,	1–1,	1	inch thick	
Base,	1–3–5,	5	inches thick	29 square feet.
Top,	1–1,	1	inch thick	
Base,	1–3–6,	3	inches thick	38 square feet.
Top,	1–1,	1	inch thick	
Base,	1–3–6,	4	inches thick	34 square feet.
Top,	1–1,	1	inch thick	
Base,	1–3–6,	5	inches thick	31 square feet.
Top,	1–1,	1	inch thick	

The exact amount of finished or rammed concrete to a given quantity of cement depends largely on the size and nature of the sand and aggregate used. A fine aggregate will have less voids, and hence will give a slightly larger amount of rammed concrete than would the same quantity of a coarser aggregate, which would require more sand and cement to fill the voids in the stone used.

CONTENTS OF CONCRETE BEAMS IN CUBIC FEET FOR EACH FOOT OF LENGTH OF BEAM.

Dimension of Beam in Inches.	Contents of Beam to each Foot of Length.	Dimension of Beam in Inches.	Contents of Beam to each Foot of Length.	Dimension of Beam in Inches.	Contents of Beam to each Foot of Length.
6×6	0.25	10×28	1.94	15×28	2.91
6×8	0.33	10×30	2.08	15×30	3.12
6×10	0.42			15×32	3.33
6×12	0.50	12×12	1.00	15×34	3.54
6×14	0.58	12×14	1.17	15×36	3.75
6×16	0.66	12×16	1.33		
6×18	0.75	12×18	1.50	16×16	1.77
6×20	0.83	12×20	1.66	16×18	2.00
6×22	0.92	12×22	1.83	16×20	2.22
6×24	1.00	12×24	2.00	16×22	2.44
		12×26	2.16	16×24	2.66
8×8	0.44	12×28	2.33	16×26	2.88
8×10	0.55	12×30	2.50	16×28	3.11
8×12	0.66			16×30	3.33
8×14	0.77	14×14	1.36	16×32	3.55
8×16	0.88	14×16	1.55	16×34	3.77
8×18	1.00	14×18	1.75	16×36	4.00
8×20	1.11	14×20	1.94		
8×22	1.22	14×22	2.14	18×18	2.25
8×24	1.33	14×24	2.33	18×20	2.50
8×26	1.44	14×26	2.53	18×22	2.75
8×28	1.55	14×28	2.72	18×24	3.00
8×30	1.66	14×30	2.91	18×26	3.25
		14×32	3.11	18×28	3.50
10×10	0.69	14×34	3.31	18×30	3.75
10×12	0.83	14×36	3.50	18×32	4.00
10×14	0.97			18×34	4.25
10×16	1.11	15×15	1.56	18×36	4.50
10×18	1.25	15×18	1.87	18×40	5.00
10×20	1.38	15×20	2.08	18×44	5.50
10×22	1.53	15×22	2.29	18×48	6.00
10×24	1.66	15×24	2.50	18×52	6.50
10×26	1.81	15×26	2.71	18×56	7.00

CONTENTS OF RECTANGULAR CONCRETE PIERS IN CUBIC FEET FOR EACH FOOT OF HEIGHT.

Size of Pier in Inches.	Contents of Pier to Each Foot of Height.	Size of Pier in Inches.	Contents of Pier to Each Foot of Height.	Size of Pier n Inches.	Contents of Pier to Each Foot of Height.
6×6	0.25	12×12	1.00	18×24	3.00
6×8	0.33	12×14	1.17	18×30	3.75
6×10	0.42	12×16	1.33		
6×12	0.50	12×18	1.50	20×20	2.77
6×14	0.58	12×20	1.66	20×24	3.33
6×16	0.66	12×24	2.00	20×30	3.47
6×18	0.75	12×30	2.50		
6×20	0.83			24×24	4.00
6×24	1.00	14×14	1.36	24×30	5.00
6×30	1.25	14×16	1.55		
		14×18	1.75	30×30	6.25
8×8	0.44	14×20	1.94	30×36	7.50
8×10	0.55	14×24	2.33	30×40	8.02
8×12	0.66	14×30	2.91	30×44	9.17
8×14	0.77			30×48	10.00
8×16	0.88	15×15	1.56		
8×18	1.00	15×18	1.87	36×36	9.00
8×20	1.11	15×20	2.08	36×40	10.00
8×24	1.33	15×24	2.50	36×44	11.00
8×30	1.66	15×30	3.12	36×48	12.00
10×10	0.69	16×16	1.77	40×40	11.11
10×12	0.83	16×18	2.00	40×44	12.22
10×14	0.97	16×20	2.22	40×48	13.33
10×16	1.11	16×24	2.66		
10×18	1.25	16×30	3.33	44×44	13.44
10×20	1.38			44×48	14.66
10×24	1.66	18×18	2.25		
10×30	2.08	18×20	2.50	48×48	16.00

RULE.—To find the contents of a pier, multiply the height of the pier in feet by the contents given in the table for a pier of the desired size. The answer will be the cubical contents of the pier in feet.

NOTE TO TABLE ON PAGE 228.—The amounts given for the top are approximate for a top having a rise or crown of about one-fourth the diameter of the cistern. These amounts will vary according to the rise given to the top.

Example.—Find the concrete required for a cistern 5 feet 6 inches inside diameter, 8 feet in depth, with walls and top 8 inches thick, and bottom 6 inches thick.

The depth of the cistern, 8 feet, plus the thickness of the top and bottom, will give a total height of the walls of 9 feet 2 inches.

By referring to the table we find for a cistern 5 feet 6 inches in diameter and walls 8 inches thick there are 12.92 cubic feet of concrete to each

CONTENTS OF ROUND CONCRETE PIERS IN CUBIC FEET FOR EACH FOOT OF HEIGHT.

Diameter of Pier. Ft.	In.	Contents of Pier to Each Foot of Height in Cubic Feet.	Diameter of Pier. Ft.	In.	Contents of Pier to Each Foot of Height in Cubic Feet.	Diameter of Pier. Ft.	In.	Contents of Pier to Each Foot of Height in Cubic Feet.
1		0.78	3		7.07	5		19.63
1	1	0.92	3	1	7.46	5	1	20.29
1	2	1.07	3	2	7.87	5	2	20.96
1	3	1.23	3	3	8.29	5	3	21.64
1	4	1.39	3	4	8.72	5	4	22.34
1	5	1.57	3	5	9.17	5	5	23.04
1	6	1.76	3	6	9.62	5	6	23.76
1	7	1.97	3	7	10.08	5	7	24.48
1	8	2.18	3	8	10.56	5	8	25.22
1	9	2.40	3	9	11.04	5	9	25.97
1	10	2.64	3	10	11.54	5	10	26.72
1	11	2.88	3	11	12.05	5	11	27.49
2		3.14	4		12.56	6		28.27
2	1	3.40	4	1	13.09	6	1	29.06
2	2	3.68	4	2	13.63	6	2	29.86
2	3	3.97	4	3	14.18	6	3	30.68
2	4	4.27	4	4	14.74	6	4	31.50
2	5	4.58	4	5	15.32	6	5	32.34
2	6	4.91	4	6	15.90	6	6	33.18
2	7	5.24	4	7	16.50	6	7	34.04
2	8	5.58	4	8	17.10	6	8	34.91
2	9	5.94	4	9	17.72	6	9	35.78
2	10	6.30	4	10	18.34	6	10	36.67
2	11	6.68	4	11	18.98	6	11	37.57

RULE.—To find the contents of a pier multiply the height of the pier in feet by the contents given in the table for the desired diameter. This will give the contents in cubic feet.

foot of wall or height. Thus, 12.92×9 feet 2 inches = 118.43 cubic feet of concrete in the walls. T ing again to the table, we find the bottom of a cistern of this size and inches thick contains 11.87 cubic feet. and the top 8 inches thick contains 18 cubic feet. By adding these sums together we have the total amount of concrete required for a cistern of the size given as follows;

Walls, 8 inches thick	118.43 cubic feet
Bottom, 6 inches thick	11.87 cubic feet
Top, 8 inches thick	18.00 cubic feet
Total	148.30 cubic feet

AMOUNT OF CONCRETE REQUIRED FOR CISTERNS OF VARIOUS SIZES.*

Inside Diameter of Cistern.		Cubic Feet of Concrete in										Sq. Feet Plaster- of ing on Wall to each Ft of Depth.	Sq. Feet of Plaster-ing in Bottom.
		Walls to Each Foot of Depth.				Bottom Inside of Wall.		Top Inside of Walls Including Manhole.					
Ft.	In.	6 Ins. Thick.	8 Ins. Thick.	10 Ins. Thick.	12 Ins. Thick.	6 Ins. Thick.	8 Ins. Thick.	6 Ins. Thick.	8 Ins. Thick.	10 Ins. Thick.	12 Ins. Thick.		
3	0	5.5	7.68	10.04	12.57	3.53	4.70	4.0	5.25	6.50	8	9.42	7.06
3	6	6.28	8.72	11.34	14.13	4.81	6.42	5.5	7.30	9.25	11	10.9	9.62
4	0	7.07	9.78	12.65	15.71	6.28	8.36	7.0	9.60	12.25	15	12.56	12.56
4	6	7.85	10.82	13.96	17.28	7.95	10.60	9.0	12.30	16.60	19	14.13	15.90
5	0	8.64	11.87	15.27	18.85	9.81	13.08	11.0	15.30	19.60	24	15.70	19.63
5	6	9.43	12.92	16.63	20.42	11.87	15.16	13.0	18.00	23.00	28	17.27	23.75
6	0	10.21	13.96	17.89	21.99	14.13	18.84	15.5	21.50	27.50	33	18.85	28.27
6	6	10.99	15.01	19.20	23.56	16.59	22.12	18.5	25.60	32.70	40	20.42	33.18
7	0	11.78	16.06	20.51	25.13	19.24	25.64	22.5	31.00	39.50	48	21.99	38.48
7	6	12.57	17.11	21.82	26.71	22.08	29.44	25.5	35.00	44.50	54	23.56	44.17
8	0	13.35	18.15	23.13	28.28	25.13	33.50	29.0	40.00	51.00	62	25.13	50.26
8	6	14.14	19.20	24.33	29.85	28.37	37.82	33.0	45.30	57.60	70	26.70	56.74
9	0	14.93	20.25	25.75	31.42	31.80	42.40	37.0	50.60	64.25	78	28.27	63.61
9	6	15.71	21.29	27.05	32.98	35.44	47.25	41.0	56.00	71.00	86	29.84	70.88
10	0	16.49	22.33	28.36	34.55	39.27	52.36	47.5	65.00	82.50	100	31.41	78.54
10	6	17.27	23.38	29.67	36.12	43.29	57.72	52.0	71.00	90.00	109	32.98	86.59
11	0	18.06	24.43	30.98	37.70	47.51	63.34	57.0	77.60	98.25	119	34.55	95.03
11	6	18.85	25.49	32.29	39.27	51.93	69.24	62.5	85.00	107.50	130	36.12	103.86
12	0	19.64	26.53	33.60	40.84	56.54	75.38	68.0	92.30	116.60	141	37.69	113.09
12	6	20.42	27.58	34.91	42.42	61.35	81.80	74	100.30	126.60	153	39.27	122.71
13	0	21.20	28.62	36.21	43.98	66.36	88.48	80	108.60	137.25	166	40.84	132.73
13	6	22.00	29.67	37.53	45.56	71.56	95.42	86	116.60	147.25	178	42.41	143.13
14	0	22.78	30.72	38.84	47.13	76.96	102.62	93	126.00	159.00	192	43.98	153.93
15	0	24.35	32.81	41.45	50.27	88.35	117.80	107	144.30	181.60	219	47.12	176.71

* See note on pp. 226, 227,

CONCRETES.

Mixtures.			Material Required for One Cubic Yard Rammed Concrete.											
			Stone, 1 Inch and Under, Dust Screened Out.			Stone, 2½ Ins. and Under, Dust Screened Out.			Stone, 2½ Ins., with Most Small Stone Screened Out.			Gravel, ¾ Inch and Under.		
Cement.	Sand.	Stone.	Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Gravel, Cu. Yds.
1	1.0	2.0	2.57	0.39	0.78	2.63	0.40	0.80	2.72	0.41	0.83	2.30	0.35	0.74
1	1.0	2.5	2.29	0.35	0.70	2.34	0.36	0.89	2.41	0.37	0.92	2.10	0.32	0.80
1	1.0	3.0	2.06	0.31	0.94	2.10	0.32	0.96	2.16	0.33	0.98	1.89	0.29	0.86
1	1.0	3.5	1.84	0.28	0.98	1.88	0.29	1.00	1.88	0.29	1.05	1.71	0.26	0.91
1	1.5	2.5	2.05	0.47	0.78	2.09	0.48	0.80	2.16	0.49	0.82	1.83	0.42	0.73
1	1.5	3.0	1.85	0.42	0.84	1.90	0.43	0.87	1.96	0.45	0.89	1.71	0.39	0.78
1	1.5	3.5	1.72	0.39	0.91	1.74	0.40	0.93	1.79	0.41	0.96	1.57	0.36	0.83
1	1.5	4.0	1.57	0.36	0.96	1.61	0.37	0.98	1.64	0.38	1.00	1.46	0.33	0.88
1	1.5	4.5	1.43	0.33	0.98	1.46	0.33	1.00	1.51	0.35	0.16	1.34	0.31	0.91
1	2.0	3.0	1.70	0.52	0.77	1.73	0.53	0.79	1.78	0.54	0.81	1.54	0.47	0.73
1	2.0	3.5	1.57	0.48	0.83	1.61	0.49	0.85	1.66	0.50	0.88	1.44	0.44	0.77
1	2.0	4.0	1.46	0.44	0.89	1.48	0.45	0.90	1.53	0.47	0.93	1.34	0.41	0.81
1	2.0	4.5	1.36	0.42	0.93	1.38	0.42	0.95	1.43	0.43	0.98	1.26	0.38	0.86
1	2.0	5.0	1.27	0.39	0.97	1.29	0.39	0.98	1.33	0.39	1.03	1.17	0.36	0.89
1	2.5	3.5	1.45	0.55	0.77	1.48	0.56	0.79	1.51	0.58	0.81	1.32	0.50	0.70
1	2.5	4.0	1.35	0.52	0.82	1.38	0.53	0.84	1.42	0.54	0.87	1.24	0.47	0.75
1	2.5	4.5	1.27	0.48	0.87	1.29	0.49	0.88	1.33	0.51	0.91	1.16	0.44	0.80
1	2.5	5.0	1.19	0.46	0.91	1.21	0.46	0.92	1.26	0.48	0.96	1.10	0.42	0.83
1	2.5	5.5	1.13	0.43	0.94	1.15	0.44	0.96	1.18	0.44	0.99	1.03	0.39	0.86
1	2.5	6.0	1.07	0.41	0.97	1.07	0.41	0.98	1.10	0.41	1.03	0.98	0.37	0.89
1	3.0	4.0	1.26	0.58	0.77	1.28	0.58	0.78	1.32	0.60	0.80	1.15	0.52	0.72
1	3.0	4.5	1.18	0.54	0.81	1.20	0.55	0.82	1.24	0.57	0.85	1.09	0.50	0.75
1	3.0	5.0	1.11	0.51	0.85	1.14	0.52	0.87	1.17	0.54	0.89	1.03	0.47	0.78
1	3.0	5.5	1.06	0.48	0.89	1.07	0.49	0.90	1.11	0.51	0.93	0.97	0.44	0.81
1	3.0	6.0	1.01	0.46	0.92	1.02	0.47	0.93	1.06	0.48	0.97	0.92	0.42	0.84
1	3.0	6.5	0.96	0.44	0.95	0.98	0.44	0.96	1.00	0.45	1.01	0.88	0.40	0.87
1	3.0	7.0	0.91	0.42	0.97	0.92	0.42	0.98	0.94	0.42	1.05	0.84	0.38	0.89
1	3.5	5.0	1.05	0.56	0.80	1.07	0.57	0.82	1.11	0.59	0.85	0.96	0.50	0.76
1	3.5	5.5	1.00	0.53	0.84	1.02	0.54	0.85	1.06	0.56	0.89	0.92	0.48	0.78
1	3.5	6.0	0.95	0.50	0.87	0.97	0.51	0.89	1.00	0.53	0.92	0.88	0.46	0.80
1	3.5	6.5	0.92	0.49	0.91	0.93	0.49	0.92	0.96	0.51	0.95	0.83	0.44	0.82
1	3.5	7.0	0.87	0.47	0.93	0.89	0.47	0.95	0.91	0.49	0.98	0.80	0.43	0.85
1	3.5	7.5	0.84	0.45	0.96	0.86	0.45	0.98	0.86	0.47	1.01	0.76	0.41	0.87
1	3.5	8.0	0.80	0.42	0.97	0.82	0.43	1.01	0.81	0.45	1.04	0.73	0.39	0.89
1	4.0	6.0	0.90	0.55	0.82	0.92	0.56	0.84	0.95	0.58	0.87	0.83	0.51	0.77
1	4.0	6.5	0.87	0.53	0.85	0.88	0.53	0.87	0.91	0.55	0.90	0.80	0.49	0.79
1	4.0	7.0	0.83	0.51	0.89	0.84	0.51	0.90	0.87	0.53	0.93	0.77	0.47	0.81
1	4.0	7.5	0.80	0.49	0.91	0.81	0.50	0.93	0.84	0.51	0.96	0.73	0.44	0.83
1	4.0	8.0	0.77	0.47	0.93	0.78	0.48	0.95	0.81	0.49	0.98	0.71	0.43	0.86
1	4.0	8.5	0.74	0.45	0.95	0.76	0.46	0.98	0.78	0.47	1.01	0.68	0.42	0.88
1	4.0	9.0	0.71	0.43	0.97	0.73	0.44	1.01	0.75	0.45	1.04	0.65	0.40	0.89
1	5.0	9.0	0.66	0.50	0.90	0.67	0.52	0.93	0.70	0.53	0.96	0.61	0.46	0.83
1	5.0	10.0	0.62	0.47	0.95	0.63	0.48	0.96	0.65	0.50	1.00	0.57	0.43	0.87

MATERIALS REQUIRED FOR BRICKWORK OF TUBULAR BOILERS.

SINGLE SETTING.

Boilers.	Common Brick.	Fire-brick.	Sand, Bushels.	Cement, Barrels.	Fire-clay, Pounds.	Lime, Barrels.
30 in. × 8 ft.	5,200	320	42	5	192	2
30 in. × 10 ft.	5,800	320	46	5½	192	2¼
36 in. × 8 ft.	6,200	480	50	6	288	2½
36 in. × 9 ft.	6,600	480	53	6½	288	2¾
36 in. × 10 ft.	7,000	480	56	7	288	3
36 in. × 12 ft.	7,800	480	62	8	288	3¼
42 in. × 10 ft.	10,000	720	80	10	432	4
42 in. × 12 ft.	10,800	720	86	11	432	4¼
42 in. × 14 ft.	11,600	720	92	11¾	432	4½
42 in. × 16 ft.	12,400	720	99	12½	432	5
48 in. × 10 ft.	12,500	980	100	12½	590	5¼
48 in. × 12 ft.	13,200	980	108	13½	590	5½
48 in. × 14 ft.	14,200	980	116	14½	590	5¾
48 in. × 16 ft.	15,200	980	124	15½	590	6
54 in. × 12 ft.	13,800	1,150	108	13¾	690	5½
54 in. × 14 ft.	14,900	1,150	117	15	690	6
54 in. × 16 ft.	16,000	1,150	126	16	690	6¼
60 in. × 10 ft.	13,500	1,280	108	13½	768	5½
60 in. × 12 ft.	14,800	1,280	118	14¾	768	6
60 in. × 14 ft.	16,100	1,280	128	16	768	6½
60 in. × 16 ft.	17,400	1,280	140	17½	768	7
60 in. × 18 ft.	18,700	1,280	148	18¾	768	7½
66 in. × 16 ft.	19,700	1,400	157	19¾	840	8
66 in. × 18 ft.	21,000	1,400	168	21	840	8½
72 in. × 16 ft.	20,800	1,550	166	20¾	930	8½
72 in. × 18 ft.	22,000	1,550	175	22	930	9

TWO BOILERS IN A BATTERY.

Boilers.	Common Brick.	Fire-brick.	Sand, Bushels.	Cement, Barrels.	Fire-clay, Pounds.	Lime, Barrels.
30 in. × 8 ft.	8,900	640	70	9	384	3½
30 in. × 10 ft.	9,600	640	76	9½	384	4
36 in. × 8 ft.	10,500	960	84	10½	576	4¼
36 in. × 9 ft.	11,100	960	88	11	576	4½
36 in. × 10 ft.	11.800	960	95	12	576	4¾
36 in. × 12 ft.	13,000	960	104	13	576	5¼
42 in. × 10 ft.	17,500	1,440	140	17½	864	7
42 in. × 12 ft.	18,600	1,440	148	18½	864	7½
42 in. × 14 ft.	19,900	1,440	159	20	864	8
42 in. × 16 ft.	21,200	1,440	168	21	864	8½
48 in. × 10 ft.	21,400	1,960	170	21½	1,180	8¾
48 in. × 12 ft.	22,300	1,960	178	22⅓	1,180	9
48 in. × 14 ft.	23,900	1,960	190	24	1,180	9½
48 in. × 16 ft.	25 100	1,960	200	25	1,180	10
54 in. × 12 ft.	23,300	2,300	186	23⅓	1,380	9⅓
54 in. × 14 ft.	24,800	2,300	198	25	1,380	10
54 in. × 16 ft.	26,300	2,300	210	26⅓	1,380	10½
60 in. × 10 ft.	22,600	2,560	180	22½	1,536	9
60 in. × 12 ft.	24,800	2,560	198	25	1,536	10
60 in. × 14 ft.	26,800	2,560	214	27	1,536	10¾
60 in. × 16 ft.	28,900	2,560	230	29	1,536	11½
60 in. × 18 ft.	31,000	2,560	248	31	1,536	12½
66 in. × 16 ft.	33,100	2,800	264	33	1,680	13¼
66 in. × 18 ft.	36,500	2,800	276	35	1,680	14
72 in. × 16 ft.	34,000	3,100	272	34	1,860	13¾
72 in. × 18 ft.	38,000	3,100	282	36	1,860	15

MATERIALS REQUIRED FOR BRICKWORK OF FIRE-BOX BOILERS, 12-INCH WALLS.

Single Setting.

Boilers.	Brick, Number.	Sand, Bushels.	Cement, Barrels.	Lime, Barrels.
30 in. × 6½ ft.	2400	20	2½	1
30 in. × 7½ ft.	2650	21	2½	1
30 in. × 8½ ft.	2900	23	2¾	1¼
36 in. × 7½ ft.	3[illegible]50	25	3	1½
36 in. × 9 ft.	3550	28	3½	1¾
36 in. × 10½ ft.	4000	31	4	2
42 in. × 8½ ft.	4000	31	4	2
42 in. × 10 ft.	4000	38	5	2¼
42 in. × 11½ ft.	5100	41	5½	2¼
48 in. × 10½ ft.	4900	40	5½	2½
48 in. × 12 ft.	5400	43	5¾	2½
48 in. × 13½ ft.	5800	46	6	2¾
54 in. × 14 ft.	6900	54	6¾	3
54 in. × 16½ ft.	7500	59	7¾	3½

MATERIALS REQUIRED FOR BRICKWORK OF FIRE-BOX BOILERS, 9-INCH WALLS.

Single Setting.

Boilers.	Brick, Number.	Sand, Bushels.	Cement, Barrels.	Lime, Barrels.
30 in. × 6½ ft.	1640	14	1½	1
30 in. × 7½ ft.	1820	15	1¾	1
30 in. × 8½ ft.	1980	16	2	1¼
36 in. × 7½ ft.	2240	18	2¼	1½
36 in. × 9 ft.	2520	20	2¾	1¾
36 in. × 10½ ft.	2870	23	3	2
42 in. × 8½ ft.	2870	23	3	2
42 in. × 10 ft.	3400	27	3½	2¼
42 in. × 11½ ft.	3800	30	4	2½
48 in. × 10½ ft.	3600	29	3¾	2¼
48 in. × 12 ft.	3860	30	4	2½
48 in. × 13½ ft.	4140	33	4½	2¾
54 in. × 14 ft.	5150	41	5½	3
54 in. × 16½ ft.	5550	43	5¾	3¼

CEMENT REQUIRED TO LAY BRICKS.

One barrel of Portland cement to 2 sand will lay about 750 brick with $\frac{3}{8}$-inch joint.

One barrel of Portland cement to 3 of sand will lay about 1050 brick with $\frac{1}{4}$-inch joint.

One barrel of Portland cement to 3 of sand will lay about 900 brick with $\frac{3}{8}$-inch joint.

One barrel of Portland cement to 3 sand will lay about 1350 brick with $\frac{1}{4}$-inch joint.

Number of Bricks Required for Chimneys.—To find the number of bricks required to build a chimney, find the number of cubic feet in the entire chimney and subtract the contents of the flues as follows:

If 8-inch flues subtract one-half the length of the flue in feet.

If 12-inch flues subtract the length of the flue in feet.

If 18-inch flues subtract $2\frac{1}{4}$ times the length of the flue in feet.

If 24-inch flues subtract four times the length of the flue in feet.

Multiply the answer by 20, which will give the number of bricks required to build the chimney.

TABLE TO FIND THE NUMBER OF BRICKS IN ANY WALL.

Superficial Feet of Wall.	Number of Bricks to Thickness of Wall.					
	4-inch.	8-inch.	12-inch.	16-inch.	20-inch.	24-inch.
1	$7\frac{1}{2}$	15	23	30	38	45
2	15	30	45	60	75	90
3	23	45	68	90	113	135
4	30	60	90	120	150	180
5	38	75	113	150	188	225
6	45	90	135	180	225	270
7	53	105	158	210	263	315
8	60	120	130	240	300	300
9	68	135	203	270	338	405
10	75	150	225	300	375	450
20	150	300	450	600	750	900
30	225	450	675	900	1,125	1,350
40	300	600	900	1,200	1,500	1,800
50	375	750	1,125	1,500	1,875	2,250
60	450	900	1,350	1,800	2,250	2,700
70	525	1,050	1,575	2,100	2,625	3,150
80	600	1,200	1,800	2,400	3,000	3,600
90	675	1,350	2,025	2,700	3,375	4,050
100	750	1,500	2,250	3,000	3,750	4,500
200	1,500	3,000	4,500	6,000	7,500	9,000
300	2,250	4,500	6,750	9,000	11,250	13,500
400	3,000	6,000	9,000	12,000	15,000	18,000
500	3,750	7,500	11,250	15,000	18,750	22,500
600	4,500	9,000	13,500	18,000	22,500	27,000
700	5,250	10,500	15,750	21,000	26,250	31,500
800	6,000	12,000	18,000	24,000	30,000	36,000
900	6,750	13,500	20,250	27,000	33,750	40,500
1,000	7,500	15,000	22,500	30,000	37,500	45,000

TABLE OF NUMBER OF BRICKS REQUIRED IN A WALL PER SQUARE FOOT OF FACE OF WALL.

4 inches	7½	24 inches	45
8 "	15	28 "	52½
12 "	22½	32 "	60
16 "	30	36 "	67½
20 "	37½	40 "	75

Example.—Find the number of bricks in a wall 8 inches thick, 5 feet high, and 10 feet long; five multiplied by ten equals 50 feet of wall 8 inches thick. Under 8 inches and opposite 50 you will find 750, the number of bricks in the wall.

The above tables are based on the usual sizes of Eastern brick; Western brick are made some larger and will take a slight percentage less than in the above tables.

SIZE OF BRICK PIERS AND NUMBER OF BRICKS REQUIRED.

Size of Pier in Inches.	Number of Bricks to Each Foot in Height.	Size of Pier in Inches.	Number of Bricks to Each Foot in Height.	Size of Pier in Inches.	Number of Bricks to Each Foot in Height.
8½ × 8½	8	22 × 30½	70	35 × 52½	192
8½ × 13	12	22 × 35	80		
8½ × 17½	16	22 × 39½	90	39½ × 39½	162
8½ × 22	20			39½ × 44	180
8½ × 26½	24	26½ × 26½	72	39½ × 48	198
		26½ × 30½	84	39½ × 52½	216
13 × 13	18	26½ × 35	96	39½ × 57	234
13 × 17½	24	26½ × 39½	108		
13 × 22	30	26½ × 44	120	44 × 44	200
13 × 26½	36			44 × 48	220
13 × 30½	42	30½ × 30½	98	44 × 52½	240
		30½ × 35	112	44 × 57	260
17½ × 17½	32	30½ × 39½	126	44 × 61	280
17½ × 22	40	30½ × 44	140		
17½ × 26½	48	30½ × 48	154	48 × 48	242
17½ × 30½	56			48 × 52½	264
17½ × 35	64	35 × 35	128	48 × 57	286
		35 × 39½	144	48 × 61	308
22 × 22	50	35 × 44	160	48 × 65½	330
22 × 26½	60	35 × 48	176		

SIZE AND NUMBER OF BRICKS REQUIRED FOR EACH SQUARE FOOT OF PAVING-BRICK.

Size of Brick.	Number Required for Each Sq. Foot.		Size of Brick.	Number Required for Each Sq. Foot.	
	Laid on Edge.	Laid on Flat.		Laid on Edge.	Laid on Flat.
2 × 4 × 8	9	4.5	3 × 4½ × 9	5.3	3.5
2¼ × 4¼ × 8¼	7.7	4.1	4 × 4 × 8	4.5	4.5
2½ × 4½ × 8½	6.7	3.7	4 × 4 × 9	4	4
2½ × 4½ × 9	6.4	3.5	4½ × 4½ × 8½	3.7	3.7
3 × 4 × 8	6	4.5	4½ × 4½ × 9	3.5	3.5
3 × 4½ × 8½	5.6	3.7			

NUMBER OF BRICK REQUIRED FOR CISTERNS.

CAPACITY AND NUMBER OF CUBIC FEET IN EXCAVATION TO EACH FOOT OF DEPTH.

Diameter of Cistern in Feet.	Depth in Feet.	Thickness of Wall Around Sides.	Number of Bricks in Wall Around Sides.	Number of Bricks in Bottom Laid Flat.	Number of Bricks in Top Arch, 4 Inches Thick.	Number of Bricks in Top Arch, 8 Inches Thick.	Square Feet of Plaster on Top and Bottom.	Sq. Ft. of Plaster on Side to Each Foot of Height.	Cu. Ft. of Excavation to each Foot of Depth.	Contents of Cistern to Each Foot of Depth in Gallons.
4	1	4	82	50	150	320	27	12.5	20	94
4	1	8	170	50	150	320	27	12.5	28	94
5	1	4	109	78	200	425	41	15.70	28	147
5	1	8	225	78	200	425	41	15.70	38	147
6	1	4	130	112	275	600	59	18.85	38	212
6	1	8	275	112	275	600	59	18.85	50	212
7	1	4	154	152	375	790	80	21.99	50	288
7	1	8	319	152	375	790	80	21.99	63	288
8	1	4	175	200	485	1000	105	25.13	63	375
8	1	8	365	200	485	1000	105	25.13	78	375
9	1	8	430	255	600	1250	135	28.27	78	476
9	1	12	615	255	600	1250	135	28.27	95	476
10	1	8	475	314	730	1525	165	31.41	113	585
10	1	12	680	314	730	1525	165	31.41	132	585
11	1	8	520	380	870	1800	200	34.55	132	710
11	1	12	740	380	870	1800	200	34.55	153	710
12	1	12	876	452	1025	2125	240	37.69	176	847
13	1	12	880	530	1175	2425	280	40.84	201	992
14	1	12	940	616	1350	2800	330	43.98	226	1153
15	1	12	1000	705	1550	3200	375	47.12	254	1340

To find the number of bricks required for a cistern: In the table opposite the required diameter find the number of bricks required per foot for the desired thickness of wall and multiply by the desired height of the cistern in feet. To this add the number required for the bottom and top.

The top should have a spring of about one-fifth the diameter. To reduce the capacity of the cistern to barrels divide by 31.5.

SIZE, ETC., OF PAVING-BRICK.—Paving-brick vary in size as much if not more than the common building-brick, therefore the size of the brick must be known to estimate correctly the number required for any particular piece of work.

The table on page 235 gives the various sizes and number of bricks required for each square foot of paving.

NUMBER OF BRICKS AND BARRELS OF CEMENT REQUIRED IN BUILDING CIRCULAR SEWERS, ETC.

TABLE OF BRICK IN CIRCULAR SEWERS, ONE FOOT IN LENGTH AND FOUR INCHES OR ONE RING THICK.

Diameter of sewer, feet	2	2½	3	3½	4	5
Number of brick	42	53	63	73	83	105
Barrels of cement per 100 lineal feet	9	11	13	15	17	20

TABLE OF BRICK IN CIRCULAR SEWERS ONE FOOT IN LENGTH AND EIGHT INCHES OR TWO RINGS THICK.

Diameter of sewer, feet	2	2½	3	3½	4	5	6	8	10
Number of brick	115	150	170	195	215	230	305	395	480
Barrels of cement per 100 lin. feet	17	19	22	25	27	34	40	60	75

TABLE OF BRICK IN EGG-SHAPED SEWERS ONE FOOT IN LENGTH AND EIGHT INCHES OR TWO RINGS THICK.

Inside dimensions, feet	2×3	2⅙×3¼	2⅓×3½	2½×3¾	2⅔×4	3×4½	3½×5¼	4×6	5×7½
No. of brick	145	160	170	178	185	205	235	260	315
Barrels of cement per 100 lineal feet	19	21	22	23	25	27	34	38	41

NUMBER OF BRICKS IN FLUSHTANKS.

(With 12-inch walls.)

Inside Diameter.	Depths in Feet.				
	5	6	7	8	9
4 feet	1124	1344	1560	1780	2000
5 feet	1417	1680	1940	2200	2460
6 feet	1820	2440	3060	3680	4300

NUMBER OF BRICK IN MANHOLES—DEPTHS BELOW BOTTOM OF COVER.

Diameter, Feet.	Height in Feet.							
	4	5	6	7	10	12	15	20
3.5	677	835	980	1125	1555	1845	2279	3007
4.0	740	880	1030	1180	1625	1948	2410	3180
4.5	830	1040	1190	1370	1910	2270	2826	3730

The above is only approximate as the sides of flushtanks and manholes have various tapers.

Flushtanks, manholes, etc., will require about 1¾ barrels of cement per 1000 brick.

Angles of Slopes.

Slopes	$\frac{1}{2}$ to 1 = 63° 30′	Slopes	$1\frac{3}{4}$ to 1 = 29° 44′
"	$\frac{3}{4}$ to 1 = 53° 00′	"	2 to 1 = 26° 35′
"	1 to 1 = 45° 00′	"	3 to 1 = 18° 25′
"	$1\frac{1}{4}$ to 1 = 38° 40′	"	4 to 1 = 14° 12′
"	$1\frac{1}{2}$ to 1 = 33° 42′		

Quantity of Earths Equal to a Ton.

Sand, river, as filled into carts	21	cu. ft.
Sand, pit, " "	22	"
Gravel, coarse " "	23	"
Marl " "	28	"
Clay, stiff " "	28	"
Chalk, lumps " "	29	"
Earth, mould " "	33	"

Natural Slopes of Earths with Horizontal Line.

Gravel	Average	40°
Dry sand	"	38°
Sand	"	22°
Vegetable earth	"	28°
Compact earth	"	50°
Shingle	"	39°
Rubble	"	45°
Clay, well drained	"	45°
Clay, wet	"	16°

Weight of Earth, Rocks, Etc.

Weight of cubic yard of sand	about	30	cwt.
" " " " " gravel	"	30	"
" " " " " mud	"	25	"
" " " " " marl	"	26	"
" " " " " clay	"	31	"
" " " " " chalk	"	36	"
" " " " " sandstone	"	39	"
" " " " " shale	"	40	"
" " " " " quartz	"	41	"
" " " " " granite	"	42	"
" " " " " trap	"	42	"
" " " " " slate	"	43	"

Cubical Contents of Trenches.—To find the cubical contents of a trench, in yards, multiply the length of the trench as follows:

1 foot cross area of trench, multiply the length by 0.037.
2 feet cross area of trench, multiply the length by 0.0741.
3 feet cross area of trench, multiply the length by 0.1111.
4 feet cross area of trench, multiply the length by 0.1481.
5 feet cross area of trench, multiply the length by 0.1851.
6 feet cross area of trench, multiply the length by 0.2222.
7 feet cross area of trench, multiply the length by 0.2952.
8 feet cross area of trench, multiply the length by 0.2692.
9 feet cross area of trench, multiply the length by 0.3333.
10 feet cross area of trench, multiply the length by 0.3703.
11 feet cross area of trench, multiply the length by 0.4078.
12 feet cross area of trench, multiply the length by 0.4444.

To find the contents of larger trenches and excavations, see pages 238 to 243.

CUBIC YARDS OF EARTH IN DITCHES WITH SIDE SLOPES OF ONE FOOT IN TEN.

Bottom Width.	Depth in Feet.											
	4	5	6	7	8	9	10	12	14	16	18	20
2 feet....	.36	.48	.60	.72	.86	.99	1.15	1.46	1.80	2.19	2.59	2.96
2½ "	.44	.57	.71	.85	1.01	1.16	1.33	1.68	2.06	2.48	2.92	3.33
3 "	.51	.66	.82	.98	1.16	1.33	1.51	1.90	2.32	2.80	3.25	3.70
3½ "	.59	.76	.93	1.11	1.30	1.49	1.70	2.12	2.58	3.30	3.58	4.07
4 "	.66	.84	1.04	1.24	1.45	1.66	1.88	2.34	2.84	3.40	3.91	4.44
4½ "	.74	.94	1.15	1.37	1.60	1.83	2.07	2.57	3.10	3.70	4.24	4.81
5 "	.81	1.04	1.26	1.50	1.75	2.00	2.25	2.80	3.36	4.00	4.57	5.18

CUBIC YARDS TO EACH FOOT OF DEPTH OF VARIOUS EXCAVATIONS.

The tables on pages 238 to 243 give the cubical contents in yards for each foot in depth of various excavations.

Example.—Find the number of yards in a cellar 24×40 feet, 8 feet deep. On page 241 we find 40 in the column of length, then follow this line out to the column under 24, the width, where we find 35.5, or 35.5 cubic yards for each foot of depth. Multiplying this by 8, we have the cubical contents of the cellar as 284 cubic yards.

NUMBER OF CUBIC YARDS IN AN EXCAVATION OR CELLAR TO EACH FOOT IN DEPTH.

FROM 2×6 TO 16×35.

Length in Feet.	Width in Feet. 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Length in Feet.
6	4	.7	9	1.1	1.3	1.5	1.7	2	2.2	2.4	2.6	2.9	3.1	3.3	3.5	6
7	.5	.8	1	1.3	1.5	1.8	2	2.4	2.6	2.8	3.1	3.4	3.6	3.9	4.1	7
8	.6	.9	1.2	1.5	1.8	2	2.4	2.6	3	3.2	3.5	3.8	4.1	4.4	4.7	8
9	.7	1	1.3	1.6	2	2.4	2.6	3	3.4	3.7	4	4.3	4.7	5	5.3	9
10	.7	1.1	1.5	1.8	2.2	2.6	3	3.4	3.7	4.1	4.4	4.8	5.2	5.5	5.9	10
11	.8	1.2	1.6	2	2.4	2.8	3.2	3.7	4.1	4.4	4.8	5.2	5.7	6.1	6.5	11
12	.9	1.3	1.8	2.2	2.6	3	3.5	4	4.4	4.8	5.2	5.7	6.2	6.6	7.1	12
13	1	1.4	1.9	2.4	2.9	3.4	3.8	4.3	4.8	5.2	5.7	6.2	6.7	7.2	7.8	13
14	1	1.5	2	2.5	3.1	3.6	4.1	4.7	5.2	5.7	6.2	6.7	7.2	7.8	8.3	14
15	1.1	1.7	2.2	2.7	3.3	3.9	4.4	5	5.5	6.1	6.7	7.2	7.8	8.3	8.9	15
16	1.2	1.8	2.3	2.9	3.5	4.1	4.7	5.3	5.9	6.5	7.1	7.8	8.3	8.9	9.5	16
17	1.3	1.9	2.5	3.1	3.8	4.4	5	5.7	6.3	6.9	7.5	8.1	8.8	9.4	10.1	17
18	1.3	2	2.6	3.3	4	4.6	5.3	6	6.6	7.3	8	8.6	9.3	10	10.6	18
19	1.4	2.1	2.8	3.5	4.2	4.9	5.6	6.3	7	7.7	8.4	9.1	9.8	10.4	11.2	19
20	1.5	2.2	2.9	3.7	4.4	5.2	5.9	6.6	7.4	8.1	8.8	9.5	10.3	11	11.8	20
21	1.5	2.3	3.1	3.9	4.5	5.3	6.2	7	7.8	8.5	9.2	10	10.8	11.6	12.4	21
22	1.6	2.4	3.2	4.1	4.9	5.7	6.5	7.3	8.1	8.9	9.7	10.5	11.4	12.2	13	22
33	1.7	2.5	3.4	4.2	5.1	5.9	6.8	7.6	8.5	9.3	10.2	11	11.9	12.7	13.6	23
24	1.8	2.6	3.5	4.4	5.2	6.1	7.1	8	8.8	9.7	10.7	11.5	12.4	13.3	14.2	24
25	1.8	2.7	3.6	4.6	5.5	6.4	7.4	8.3	9.2	10.1	11.1	12	12.9	13.8	14.8	25
26	1.9	2.9	3.8	4.8	5.8	6.7	7.7	8.6	9.6	10.6	11.5	12.5	13.5	14.4	15.4	26
27	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	27
28	2.1	3.1	4.1	5.1	6.2	7.3	8.3	9.3	10.3	11.4	12.4	13.5	14.5	15.5	16.6	28
29	2.1	3.2	4.3	5.3	6.4	7.5	8.5	9.6	10.7	11.8	12.9	14	15	16.1	17.2	29
30	2.2	3.4	4.4	5.5	6.6	7.7	8.8	10	11.1	12.2	13.3	14.4	15.5	16.6	17.7	30
31	2.3	3.4	4.6	5.7	6.8	8	9.2	10.3	11.5	12.6	13.7	14.9	16	17.1	18.3	31
32	2.4	3.5	4.7	5.9	7.1	8.3	9.5	10.6	11.8	13	14.2	15.4	16.6	17.7	18.9	32
33	2.4	3.6	4.9	6.1	7.3	8.5	9.8	11	12.2	13.4	14.6	15.9	17.1	18.2	19.5	33
34	2.5	3.7	5	6.3	7.5	8.8	10.1	11.4	12.6	13.8	15.1	16.3	17.6	18.8	20.1	34
35	2.6	3.9	5.1	6.5	7.8	9	10.4	11.7	13	14.2	15.5	16.7	18	19.2	20.7	35

NUMBER OF CUBIC YARDS IN AN EXCAVATION OR CELLAR TO EACH FOOT IN DEPTH—(*Continued*).

FROM 17 × 6 TO 30 × 35.

	Width in Feet.														
Length in Feet.	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Length in Feet.
6	3.8	4	4.2	4.4	4.5	4.9	5.1	5.2	5.5	5.8	6	6.2	6.4	6.6	**6**
7	4.4	4.6	4.9	5.2	5.3	5.7	5.9	6.1	6.4	6.7	7	7.3	7.5	7.7	**7**
8	5	5.3	5.6	5.9	6.2	6.5	6.8	7.1	7.4	7.7	8	8.3	8.5	8.8	**8**
9	5.7	6	6.3	6.6	7	7.3	7.6	8	8.3	8.6	9	9.3	9.6	10	**9**
10	6.3	6.6	7	7.4	7.8	8.1	8.5	8.8	9.2	9.6	10	10.3	10.7	11.1	**10**
11	6.9	7.3	7.7	8.1	8.5	8.9	9.3	9.7	10.1	10.6	11	11.4	11.8	12.2	**11**
12	7.5	8	8.4	8.8	9.2	9.7	10.2	10.7	11.1	11.5	12	12.4	12.9	13.2	**12**
13	8.1	8.6	9.1	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.4	**13**
14	8.8	9.3	9.8	10.3	10.8	11.4	11.9	12.4	13.9	13.5	14	14.5	15	15.5	**14**
15	9.4	10	10.4	11	11.6	12.2	12.7	13.3	13.8	14.4	15	15.5	16.1	16.6	**15**
16	10.1	10.6	11.2	11.8	12.4	13	13.6	14.2	14.8	15.4	16	16.6	17.2	17.7	**16**
17	10.7	11.3	11.9	12.5	13.3	13.8	14.4	15.1	15.7	16.3	17	17.7	18.3	18.8	**17**
18	11.3	12	12.6	13.3	14	14.7	15.3	16	16.7	17.3	18	18.7	19.3	20	**18**
19	11.9	12.6	13	14.1	14.7	15.5	16.1	16.8	17.5	18.3	19	19.7	20.3	21.1	**19**
20	12.5	13.3	14.1	14.8	15.5	16.3	17	17.7	18.4	19.2	20	20.7	21.4	22.2	**20**
21	13.3	14	14.7	15.5	16.3	17.1	17.9	16.6	19.3	20.1	21	21.7	22.5	23.3	**21**
22	13.8	14.7	15.5	16.3	17.1	18	18.8	19.5	20.3	21.1	22	22.8	23.6	24.4	**22**
23	14.4	15.3	16.1	17	17.9	18.8	19.6	20.4	21.2	22.1	23	23.8	24.6	25.5	**23**
24	15.1	16	16.8	17.7	18.6	19.5	20.4	21.3	22.2	23.1	24	24.9	25.7	26.6	**24**
25	15.7	16.7	17.5	18.4	19.3	20.3	21.2	22.2	23.1	24	25	25.9	26.8	27.7	**25**
26	16.3	17.3	18.3	19.2	20.1	21.1	22.1	23.1	24	25	26	27	27.9	28.9	**26**
27	17	18	19	20	21	22	23	24	25	26	27	28	29	30	**27**
28	17.7	18.7	19.7	20.7	21.7	22.8	23.8	24.9	25.9	27	28	29	30	31.1	**28**
29	18.3	19.3	20.3	21.4	22.5	23.6	24.6	25.7	26.8	27.9	29	30	31.1	32.2	**29**
30	18.8	20	21.1	22.2	23.3	24.4	25.5	26.6	27.7	28.9	30	31.1	32.2	33.3	**30**
31	19.4	20.7	21.7	22.9	24	25.1	26.3	27.5	28.3	29.8	31	32.1	33.2	34.4	**31**
32	20.1	21.4	22.5	23.7	24.8	25.9	27.2	28.4	28.9	30.8	32	33.1	34.3	35.5	**32**
33	20.7	22	23.2	24.4	25.6	26.8	28.1	29.3	29.6	31.7	33	34.2	35.4	36.6	**33**
34	21.4	22.7	23.9	25.1	26.4	27.7	29	30.2	31.4	32.7	34	35.2	36.5	37.7	**34**
35	22	23.3	24.6	25.9	27.2	28.6	29.9	31.1	32.2	33.6	35	36.2	37.5	38.8	**35**

NUMBER OF CUBIC YARDS IN AN EXCAVATION OR CELLAR TO EACH FOOT IN DEPTH—(*Continued*).

FROM 2×36 TO 16×65.

Length in Feet.	Width in Feet. 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Length in Feet.
36	2.6	4	5.3	6.6	8	9.3	10.6	12	12.3	14.6	16	17.3	18.6	20	21.3	36
37	2.7	4.1	5.5	6.8	8.2	9.6	10.9	12.3	12.7	15	16.4	17.8	19.1	20.5	21.9	37
38	2.8	4.2	5.6	7	8.4	9.8	11.2	12.6	14	15.4	16.8	18.3	19.7	21.1	22.5	38
39	2.8	4.3	5.8	7.2	8.6	10.1	11.5	13	14.4	15.8	17.3	18.8	20.2	21.6	23.1	39
40	2.9	4.4	5.9	7.4	8.8	10.3	11.[illegible]	13.3	14.8	1[illegible].2	17.7	19.2	20.7	22.2	23.7	40
41	3	4.5	6.1	7.6	9	10.6	12.1	13.6	15.2	16.6	18.1	19.7	21.2	22.7	24.3	41
42	3.1	4.6	6.2	7.7	9.3	10.8	12.4	14	15.5	17.1	18.6	20.2	21.7	23.3	24.8	42
43	3.1	4.7	6.3	7.9	9.5	11.1	12.7	14.3	15.9	17.5	19	20.7	22.2	23.8	25.4	43
44	3.2	4.8	6.5	8.1	9.7	11.3	13	14.6	16.2	17.9	19.5	21.1	23.7	24.4	26	44
45	3.3	4.9	6.7	8.[illegible]	9.9	11.6	13.3	15	16.6	18.4	19.9	21.6	23.2	24.9	26.6	45
46	3.4	5.1	6.8	8.5	10.2	11.9	13.6	15.3	17	18.7	20.4	22.1	23.8	25.5	27.2	46
47	3.4	5.2	7	8.7	10.4	12.1	13.9	15.6	17.4	19.1	20.8	22.6	24.3	26	27.8	47
48	3.5	5.3	7.1	8.[illegible]	10.6	12.4	14.2	16	17.[illegible]	19.5	21.3	23.1	24.8	26.6	28.4	48
49	3.5	5.4	7.3	9.1	1[illegible].8	12.7	14.5	16.3	18.1	19.9	21.7	23.6	25.3	27.1	29.2	49
50	3.6	5.5	7.4	9.2	11.1	12.9	14.8	16.6	18.4	20.[illegible]	22.1	24	25.8	27.7	29.5	50
51	3.7	5.6	7.6	9.3	11.3	13.1	15.1	17	18.[illegible]	20.7	22.5	24.5	26.3	28.2	30.1	51
52	3.8	5.7	7.7	9.6	11.5	13.4	15.4	17.3	19.2	21.1	23	25	26.9	28.8	30.7	52
53	3.9	5.9	7.9	9.8	11.7	13.7	15.7	17.6	19.6	21.5	23.5	25.5	27.4	29.4	31.3	53
54	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	54
55	4.1	6.1	8.2	10.2	12.2	14.3	16.3	18.3	20.4	22.4	24.4	26.5	28.5	30.5	32.6	55
56	4.1	6.2	8.3	10.[illegible]	12.4	14.5	16.[illegible]	18.6	20.7	22.8	24.9	27	29.1	31.1	33.2	56
57	4.2	6.3	8.5	10.6	12.6	14.8	16.9	19	21.1	23.2	25.3	27.5	29.6	31.6	33.8	57
58	4.3	6.5	8.6	10.7	12.8	15	17.1	19.3	21.[illegible]	23.6	25.8	27.9	30.1	32.2	34.4	58
59	4.3	6.5	8.8	10.9	13	15.3	17.4	19.6	21.9	24	26.2	28.4	30.6	32.7	35	59
60	4.4	6.6	8.9	11.1	13.3	15.5	17.7	20	22.2	24.4	26.6	28.8	31.1	33.3	35.5	60
61	4.5	6.7	9.1	11.3	13.5	15.8	18	20.3	22.6	24.8	27	29.4	31.5	33.8	36.1	61
62	4.6	6.9	9.2	11.5	13.7	16	18.3	20.[illegible]	22.9	25.2	27.5	29.8	32.1	34.4	36.7	62
63	4.6	7	9.3	11.6	13.9	16.3	18.6	21	23.3	25.7	27.9	30.3	32.6	35	37.3	63
64	4.7	7.1	9.5	11.8	14.2	16.5	18.9	21.3	23.6	26	28.3	30.8	33.1	35.5	37.8	64
65	4.8	7.2	9.6	12	14.4	16.8	19.2	21.6	24	26.5	28.9	31.3	33.7	36.1	38.5	65

NUMBER OF CUBIC YARDS IN AN EXCAVATION OR CELLAR TO EACH FOOT IN DEPTH—(*Continued*).
FROM 17×36 TO 30×65.

Length in Feet.	Width in Feet 17	18	19	20	21	22	23	24	25	26	27	28	29	30	Length in Feet.
36	21.6	24	25.3	26.6	28	29.3	30.6	32	33.3	34.6	36	37.3	38.6	40	36
37	22.2	24.6	26	27.3	28.7	30.1	31.5	32.8	34.2	35.5	37	38.3	39.7	41.1	37
38	23.9	25.3	26.7	28.1	29.5	30.9	32.3	33.7	35.1	36.5	38	39.4	40.8	42.2	38
39	24.5	26	27.4	28.9	30.3	31.8	33.1	34.6	36	37.5	39	40.4	41.9	43.3	39
40	25.1	26.6	28.1	29.6	31.1	32.6	34	35.5	37	38.5	40	41.5	42.9	44.4	40
41	25.7	27.3	28.8	30.3	31.8	33.4	34.8	36.4	37.9	39.4	41	42.5	44	45.5	41
42	26.4	28	29.5	31.1	32.6	34.2	35.7	37.3	38.8	40.4	42	43.5	45	46.6	42
43	27	28.6	30.2	31.9	33.4	35	36.5	38.2	39.8	41.4	43	44.6	46.1	47.7	43
44	27.7	29.3	30.9	32.6	34.2	35.8	37.4	39.1	40.7	42.3	44	45.6	47.2	48.8	44
45	28.3	30	31.6	33.3	35	36.6	38.2	40	41.6	43.3	45	46.6	48.3	49.9	45
46	28.9	30.6	32.3	34	35.7	37.4	39.1	40.8	42.5	44.3	46	47.7	49.4	51.1	46
47	29.5	31.3	33	34.8	36.5	38.3	39.9	41.7	43.4	45.2	47	48.7	50.4	52.2	47
48	30.2	32	33.8	35.5	37.3	39.1	40.8	42.6	44.3	46.1	48	49.7	51.5	53.3	48
49	30.8	32.6	34.5	36.3	38.1	39.9	41.6	43.5	45.3	47.1	49	50.8	52.6	54.4	49
50	31.4	33.3	35.1	37	38.8	40.7	42.5	44.4	46.2	48.1	50	51.8	53.7	55.5	50
51	32	34	35.8	37.3	39.6	41.5	43.3	45.3	47.1	49.1	51	52.8	54.7	56.6	51
52	32.7	34.6	36.5	38.5	40.4	42.3	44.2	46.2	48	50	52	53.9	55.8	57.7	52
53	33.3	35.3	37.2	39.3	41.2	43.1	45.1	47.1	49	51	53	54.9	56.9	59.9	53
54	34	36	38	40	42	44	46	48	50	52	54	56	58	60	54
55	34.6	36.6	38.7	40.7	42.8	44.8	46.8	48.9	50.9	52.9	55	57	59	61.1	55
56	35.2	37.3	39.4	41.4	43.5	45.6	47.6	49.7	51.8	53.9	56	58	60.1	62.2	56
57	35.8	38	40.1	42.1	44.3	46.4	48.4	50.6	52.7	54.8	57	59.1	61.1	63.3	57
58	35.5	38.6	40.8	42.9	45.1	47.2	49.3	51.5	53.7	55.8	58	60.1	62.2	64.4	58
59	37.1	39.3	41.5	43.6	45.9	48	50.2	52.4	54.6	56.8	59	61.1	63.3	65.5	59
60	37.7	40	42.2	44.4	46.6	48.8	51	53.3	55.5	57.7	60	62.2	64.4	66.6	60
61	38.3	40.6	42.9	45.1	47.4	49.6	51.9	54.2	56.5	58.7	61	63.2	65.5	67.7	61
62	39	41.3	43.6	45.9	48.2	50.5	52.8	55.1	57.4	59.7	62	64.2	66.6	68.8	62
63	39.6	42	44.2	46.6	49	51.3	53.6	56	58.3	60.6	63	65.3	67.6	69.9	63
64	40.2	42.6	44.9	47.4	49.7	52.1	54.4	56.8	59.2	61.6	64	66.3	68.7	71.1	64
65	40.9	43.3	45.7	48.1	50.5	52.9	55.3	57.7	60.1	62.5	65	67.4	69.9	72.2	65

NUMBER OF CUBIC YARDS IN AN EXCAVATION OR CELLAR TO EACH FOOT IN DEPTH—(*Continued*).
FROM 31×36 TO 40×65.

Length in Feet.	Width in Feet.										Length in Feet.
	31	32	33	34	35	36	37	38	39	40	
36	41.3	42.6	44	45.3	46.7	48	49.3	50.7	52	53.4	**36**
37	42.4	43.8	45.2	46.9	48	49.3	50.7	52.1	53.5	54.9	**37**
38	43.6	45	46.4	47.9	49.3	50.7	52.1	53.5	54.9	56.3	**38**
39	44.8	46.2	47.6	49.1	50.7	52	53.5	54.9	56.3	57.8	**39**
40	46	47.4	48.8	50.3	51.8	53.4	54.9	56.3	57.8	59.2	**40**
41	47.1	48.5	50	51.5	54.1	54.7	56.2	57.7	59.2	60.7	**41**
42	48.2	49.7	51.3	52.8	54.4	56	57.6	59.1	60.6	62.2	**42**
43	49.3	50.9	52.5	54.1	55.7	57.3	59	60.5	62.1	63.7	**43**
44	50.5	52.1	53.7	55.4	57	58.7	60.4	61.9	63.5	65.2	**44**
45	51.7	53.3	54.9	56.6	58.3	60	61.7	63.3	64.9	66.6	**45**
46	52.8	54.5	56.2	57.9	59.6	61.3	63.1	64.7	66.4	68.1	**46**
47	53.9	55.6	57.4	59.1	60.9	62.7	64.5	66.1	67.8	69.6	**47**
48	55.1	56.8	58.6	60.4	62.2	64	65.8	67.5	69.3	71.1	**48**
49	56.3	57.7	59.8	61.6	63.5	65.3	67.2	68.9	70.8	72.6	**49**
50	57.4	59.2	61.1	62.9	64.8	66.7	68.6	70.3	72.2	74	**50**
51	58.6	60.4	62.3	64.2	66.1	68	69.8	71.7	73.6	75.5	**51**
52	59.7	61.6	63.5	65.5	67.4	69.3	71.2	73.1	75	77	**52**
53	60.9	62.8	64.7	66.7	68.7	70.7	72.6	74.5	76.5	78.5	**53**
54	62	64	66	68	70	72	74	76	78	80	**54**
55	63.2	65.2	67.2	69.2	71.3	73.3	75.3	77.4	79.4	81.5	**55**
56	64.3	66.3	68.4	70.5	72.6	74.7	76.7	78.8	80.8	82.9	**56**
57	65.5	67.5	69.6	71.7	73.9	76	78.1	80.2	82.3	84.4	**57**
58	66.6	68.7	70.9	73	75.2	77.3	79.4	81.6	83.7	85.9	**58**
59	67.7	69.9	72.1	74.2	76.5	78.7	80.9	83	85.2	87.4	**59**
60	68.8	71	73.3	75.5	77.7	80	82.2	84.4	86.6	88.8	**60**
61	70	72.3	74.7	76.8	79	81.3	83.5	85.8	88	90.3	**61**
62	71.1	73.3	75.7	78.1	81.4	82.7	84.9	87.2	89.5	91.8	**62**
63	72.3	74.7	77.1	79.3	81.7	84	86.3	88.6	90.9	93.3	**63**
64	73.5	75.9	78.2	80.6	82.9	85.3	87.6	90	92.4	94.8	**64**
65	74.7	76.2	79.7	81.9	84.2	86.7	89	91.4	93.8	96.3	**65**

NUMBER OF CUBIC YARDS IN AN EXCAVATION OR CELLAR TO EACH FOOT IN DEPTH—(*Continued*).
FROM 41 × 36 TO 50 × 65

Length in Feet	Width in Feet. 41	42	43	44	45	46	47	48	49	50	Length in Feet.
36	54.7	56	57.3	58.7	60	61.3	62.7	64	65.3	66.7	**36**
37	56.2	57.6	59	60.4	61.7	63.1	64.5	65.8	67.2	68.6	**37**
38	57.7	59.1	60.5	61.9	63.3	64.7	66.1	67.5	68.9	70.3	**38**
39	59.2	60.6	62.1	63.5	64.9	66.4	67.8	69.3	70.8	72.2	**39**
40	60.7	62.2	63.7	65.2	66.6	68.1	69.6	71.1	72.6	74	**40**
41	61.5	63.7	65.3	66.8	68.3	69.8	71.3	72.8	74.3	75.8	**41**
42	63.7	65.3	66.9	68.5	70	71.5	73.1	74.6	76.1	77.7	**42**
43	65.3	66.9	68.5	70.1	71.6	73.2	74.8	76.4	78	79.6	**43**
44	66.8	68.5	70.1	71.7	73.3	74.9	76.5	78.2	79.9	81.5	**44**
45	68.3	70	71.6	73.3	75.7	76.6	78.2	79.9	81.6	83.3	**45**
46	69.8	71.5	73.2	74.9	76.6	78.3	80	81.7	83.4	85.1	**46**
47	71.3	73.1	74.8	76.5	78.2	80	81.8	83.5	85.2	86.9	**47**
48	72.8	74.6	76.4	78.2	79.9	81.7	83.5	85.3	87	88.8	**48**
49	74.3	76.1	78	79.9	81.6	83.4	85.2	87	88.9	90.4	**49**
50	75.8	77.7	79.6	81.5	83.3	85.1	86.9	88.8	90.4	92.5	**50**
51	77.4	79.3	81.1	83.1	84.9	86.8	88.7	90.5	92.3	94.4	**51**
52	78.9	80.9	82.6	84.7	86.6	88.6	90.4	92.2	94.2	96.3	**52**
53	80.5	82.5	84.3	86.3	88.3	90.3	92.2	94.1	96.1	98.1	**53**
54	82	84	86	88	90	92	94	96	98	100	**54**
55	83.5	85.6	87.6	89.6	91.7	93.7	95.8	97.8	99.8	101.8	**55**
56	85	87.1	89.2	91.2	93.3	95.4	97.5	99.5	101.6	103.7	**56**
57	86.5	88.6	90.7	92.8	95	97.1	99.2	101.3	103.4	105.5	**57**
58	87.9	90	92.2	94.5	96.7	98.8	101	103.1	105.3	107.4	**58**
59	89.5	91.6	98.8	96.1	98.3	100.2	102.7	104.8	106.6	109.2	**59**
60	91	93.3	95.5	97.7	99.9	102.2	104.4	106.6	108.8	111.1	**60**
61	92.6	94.9	97.1	99.3	101.6	103.9	106.1	108.4	110.6	112.9	**61**
62	94.1	96.4	98.7	101	103.3	105.6	107.9	110.2	112.5	114.8	**62**
63	95.6	98	100.2	102.5	104.9	107.2	109.6	111.9	114.3	116.6	**63**
64	97.1	99.5	101.7	104	106.5	109	111.3	113.7	116.1	118.5	**64**
65	98.7	101.1	103.5	105.9	108.3	110.7	112.1	115.5	117.9	120.3	**65**

PART V.

CEMENT BUILDING BLOCKS, MATERIALS AND MANUFACTURE OF CEMENT BLOCKS, MANUFACTURE AND USE OF SPECIAL BLOCKS, MAKING AND USING SPECIAL MOULDS, CASTING CEMENT STONE OR BLOCKS, SPECIFICATIONS FOR BLOCKS, BUILDING REGULATIONS FOR USE OF BLOCKS, TESTS OF BUILDING BLOCKS.

Cement Building-blocks.—There are two processes of making cement building-blocks, which are known as the "dry" process and the "wet" process. With the wet process the cement mixture is made thin enough to be poured or puddled into the mould, and then let stand until the cement has set and the moulds can be removed. This process requires a number of moulds, as it takes several hours for the cement to set hard enough so the moulds can be removed from the block.

With the "dry" process the mixture is given just enough water to give it the consistency of damp earth, and which when tamped into place will stand up when the moulds are removed. In this process the block after being moulded is carried away on a pallet and another block is formed, thus using the same moulds over and over continuously.

Either process results in good work when done correctly, but for a water-proof block the author prefers the use of what might be termed a "medium wet" mixture, one that requires

tamping into place, but from which with care the moulds can be removed as soon as the block is made.

Regarding the making of blocks the following extract is taken from an article in a recent issue of *Cement Age*, by S. B. Newberry, manager, Sandusky Portland Cement Co.:

"It is well known that a concrete mixed fairly wet is far better than one made too dry. This difference is, however, not due to lack in the dry concrete of moisture required for the crystallization of the cement. This quantity is extremely small, and amounts to not more than 3 per cent of the weight of a 1 to 5 mixture. Even the dryest damp-tamped block mixture contains much more water than this. The effect of a liberal supply of water is to cause the mixture to settle together and become dense, in the same way as loose filled ground is compacted by flooding it with a hose-stream. If made too dry, concrete will always be loose, porous and crumbling, and no amount of subsequent sprinkling or soaking will help matters. Now, it requires less labor to make blocks from a rather dry mixture than from a sufficiently wet one, and more blocks per day can be turned out, per man and per machine, if the proportion of water is kept low. It is no wonder, therefore, that block-makers turn out poor stuff unless checked by tests of product or shown the error of their ways. Nevertheless, *it is perfectly possible to use enough water to make the mass thoroughly plastic and yield concrete of the highest quality and strength, and still to remove the blocks at once from the machine.* Left to themselves, the workers will always make the blocks too dry; it is merely a question of intelligent and careful supervision. *As much water must be used as possible without causing the blocks to stick to the plates or sag out of shape on removing from the machine.* If block-makers will conscientiously try this they will be surprised to find how wet a mixture can successfully be used, and how greatly the quality of their work is improved thereby.

"Many attempts have been made to produce hollow blocks by pouring semi-liquid concrete into a separable mould, in which it was allowed to harden for twenty-four hours or longer before removal. Very strong blocks are obtained in this way, though no better than by the damp-tamping process if correctly conducted. The poured blocks have one great drawback, however, and that is their ugliness. In all concrete made very wet, a film of neat cement is formed on the surface, which gives the work a lifeless look and is liable to show hair-cracks and light

streaks and patches. Damp-tamped work, on the other hand, if properly made, shows a granular sandy surface and uniform color. The damp-tamping process, therefore, is far superior to wet process in economy and beauty of product, and with proper care can be made fully equal in strength. There is no difficulty in obtaining at twenty-eight days a crushing strength of 2000 pounds per square inch, using a 1 to 5 mixture of cement, sand, and coarse gravel, and removing the blocks from the machine as fast as made."

Objections to Concrete Blocks.—The main objection to concrete blocks has been the similarity of the blocks used. The various machines not having a sufficient variety of moulds and producing a number of blocks exactly alike for use in the same building.

The majority of blocks used are what is known as "rock face," and in a building there will often be but two or three different faces used.

This block work is an imitation of stonework, but in a stone building of "rock face" work, no two stones can be found with "faces" alike.

In a paper presented before the National Association of Concrete Users, 1907, A. O. Elzner, said:

"At present the tendency in the manufacture of these blocks is to imitate split faces of stone ashlar. This is radically wrong in principle and should not be tolerated. A flat, smooth face will always look well. However, if a pitched or split face is desired, let it be produced by casting the block flat and then pitching off the face with chisel and hammer, just as is done with stone. The clean fracture of the concrete thus exposed will be eminently effective and artistic and will have all the merit that belongs to truthfulness. Plain concrete ashlar walls might in some cases be effectively relieved by the introduction of bands of decorated blocks with some simple ornament moulded in the face, very much as is done with terra-cotta, but by all means avoid moulded rock-faced work. It is artistically bad. The frequent and constant repetition of a few regular sizes and patterns, ruins an effect which should be counted largely as accidental but always expressive of a fine artistic sense in the selection and grouping of the individual blocks. Artificiality, imitation and misrepresentation are stamped all over such work and can be recognized at first glance."

To overcome this objection of similarity use a number of

designs and make a variety of "faces" for each size block. Also have moulds or be able to make them to produce any shape or size blocks an architect drawing may call for. Do not expect the architect to design his building to fit your blocks, but make your blocks to conform to his size and drawings, the same as the stone-cutter cuts his stone to conform to the architect's drawing.

S. B. Newberry, in *Cement Age*, recently said: "Much of the discredit and opposition which concrete blocks have encountered has been due to the feeling that they are a sham and an imitation. This is of course repugnant to all who hold the belief expressed in the last lines of Keats' "Ode on a Grecian Urn,"

> "'Beauty is truth, truth beauty, that is all
> Ye know on earth, and all ye need to know.'

"So long as the imitation of stone by concrete consists only of similarity in texture and color, no fault can be found with it. Concrete consisting of grains of sand and gravel or fragments of crystalline limestone, joined together by cement, must necessarily look like stone, because it is stone, and made up of stony materials. But when we imitate in our blocks the irregularly fractured surface of quarried rock, and worse still, make a multitude of suck blocks from a single mould, we are committing a fraud, and one so transparent as to be detected at a glance by all but the most unobserving. It is no wonder that architects despise the rock-faced cement-block; the surprising thing is that the public has endured it so long."

Rock-faced blocks can be made by making blocks with a face of sand and cement about $2\frac{1}{2}$ inches thick, and after the blocks are two or three days old, take a stone-cutters' "pitching" tool and put on a rock-face the same as putting a rock-face on a stone. This will give the blocks the appearance of stone and no two will be alike.

Aggregate.—The aggregate for making cement blocks can be either broken stone, gravel, or slag, or a combination of any of these; that which can be obtained the cheapest should of course be used.

If broken stone is used it should be broken to pass a 1-inch mesh screen, and if gravel, it should be screened through a screen of this size.

If the broken stone contains much dust it should be run over a small mesh screen to take out this dust. Or another

method is to wash out the dust. This can be done by putting a bottom of sieve wire in a barrel, then filling the barrel with the stone and running water through the stone, letting it run out through the sieve end, thus washing out all dust and dirt.

If the gravel to be used contains much clay or earthy matter it should be washed as described to take out all dirt.

Crushed slag is also used to some extent as an aggregate for making cement blocks. It should be well seasoned, as fresh slag is more susceptible to the effects of heat and cold as regards expansion and contraction than it is after it has attained some age and is well seasoned. If containing much dust it should be washed.

Slag being light in color, and lighter in weight than stone or gravel, it produces a block both light in color and in weight.

Sand.—The sand for concrete blocks should be such as described on page 48. When a special mixture is to be used for the face of the block the sand for this mixture should be selected and can be finer than that used in the body of the block.

That for the face must be perfectly clean, and if not so should be washed before being used.

The sand for the body of the block may contain 5 per cent of clay, and which will not affect the strength of the block, but any earthy or vegetable matter should be washed out, as it will cause a weak block.

Wet sand should not be used, as it causes the cement to form into smalls and starts its set during the dry mixing.

Slag which has been pulverized by turning water on it while hot, has been used recently as a sand for making cement blocks, and as far as used, has given good results. It makes a block of a very light color when used with a light colored cement.

Sand and gravel combined, as it comes from the pit or river bed, is often used for making blocks. This is poor policy, for the sand and gravel is not distributed uniformly in the pit or bed, nor is it in the correct proportions. If used in this way, some blocks would have too much sand and some not enough, or one would have too much gravel and another not enough, as the case would be.

When the sand and gravel is obtained from the same pit or bed they should first be separated by screening, and then remixed in the proportions desired. This will make a uniform mixture, and can be obtained in no other way.

The Mixture.—The proportions for making the mixture for blocks will depend on the strength desired and the materials used.

To make a good dense block there must be enough cement used to fill the voids of the sand, and enough of sand and cement to fill the voids in the aggregate.

When the entire block is made of sand and cement, 1 part cement and 4 parts sand will make a good block.

When an aggregate is used, the mixture should be 1 part cement, 3 parts sand, and 5 parts of the aggregate; this will make a strong and nearly water-proof block.

Mixing.—When the amount of work to be done will justify the first expense, a power mixer should be purchased, and which will prove cheapest in the end, and will also be the most convenient method of mixing.

The materials used should be carefully measured, so as to have the different "batches" of concrete of the same proportions and strength.

In machine mixing the proportions of cement, sand, and aggregate should be mixed thoroughly while dry, or until the mixture shows a uniform color, then the water should be added in just sufficient quantity to make a soft plastic mixture, which will tamp readily in the moulds, but will stand up when the moulds are carefully removed.

When the mixing is done by hand with shovels or hoes, it should be done on a water-tight platform, which should have a rim around it to keep the mixture from running off.

The sand and cement should be mixed dry and then water added to make a mortar of the consistency described above, then the aggregate, which should be wet, should be added, and the whole mass thoroughly mixed, until each and every piece of the aggregate is covered with a coat of the mortar, and the mortar and the aggregate are distributed uniformly through the mass.

When blocks are made without any large aggregate the mixing can be done in a box as follows:

The sand should be measured and put into the box in a uniform layer, the cement should then be measured and spread evenly over the sand. Now with a hoe turn the mixture to the end of the box and back several times, until it becomes of a uniform color. Add the water and mix thoroughly by turning the mass over and over several times. Use as much water as possible without causing the block to fall down after being moulded, or causing it to stick to the moulds.

Coloring Blocks.—Various shades and colors can be obtained by the use of different cements and different colors of sand. For instance, a blue cement and light colored sand will produce a light blue block.

It is a good idea for any person in the cement block business to keep on hand a sample block of each color he can make with the various cements. With these to select from it is very easy then for a customer to select the color he desires.

For coloring blocks with coloring materials, use those given on page 78.

In coloring the blocks the wet mixture should be colored several shades darker that the color desired in the finished block, as the wet mortar looks darker and brighter to the eye (owing to the gloss of the water) than it really is.

Cement blocks should not be made too dark, as this is contrary to nature; all natural stones being of a rather light color.

In mixing the coloring material, mix the sand, cement, and coloring material dry, until the mass becomes a uniform color, then add the water.

Making the Block.—When the moulds are prepared, and the concrete or mortar mixed as previously explained, put in the moulds a layer of the mixture about 3 inches deep and tamp thoroughly, then put in another layer and tamp again, repeating the operation until the mould is full and the block completed.

To make the blocks the same consistency throughout, the tamping must be thorough, and all parts tamped uniformly, so that all parts of the block will be of the same solidity and denseness.

The mixture should be tamped until the water comes to the top and all particles made compact, with no voids or air spaces.

The tamping should be done with light quick blows, as a number of light blows will pack more thoroughly than a few heavy ones.

When the blocks are made face down and a special mixture is used for the face, this mixture should be put in the mould of the thickness desired and tamped before the body mixture is put in.

When made the block should be carefully removed from the mould and set away to season.

Curing Cement Building Blocks.—Curing or seasoning the blocks is done by keeping the freshly made block wet for

several days after being made, so as to give moisture enough to cause correct crystallization of the cement.

The blocks as soon as made should be put in a shed or some protected place and kept thoroughly wet with water for several days.

As soon as the blocks are hard enough, which will be in eight or ten hours after being made, they should be sprinkled thoroughly, and this should be repeated twice each day for about a week, or if a curing shed is used and made tight, steam can be used for curing the blocks by filling the room with steam; the blocks will absorb the moisture.

When sprinkling blocks great care should be exercised not to wash or disfigure the arrises or corners of the blocks, and to preserve as sharp an outline as possible on all relief work.

The blocks while curing should be protected from all draughts of air, and also from the sun's rays, which would cause them to dry too fast. If the blocks are being cured in the open air they should be kept covered with wet burlap to protect them and to hold the moisture.

Care of Machine and Molds.—At the close of each day's work the machine, moulds, and all tools should be washed clean and put in place for commencing the next day's work.

The moulds should be wiped dry and then wiped with a piece of waste saturated with crude oil. This will prevent them from rusting, and also keep the newly-made block from sticking to the moulds.

At intervals, the entire machine should be cleaned of all dirt, mortar, etc., and wiped with the oil waste.

All gearing mechanism, working joints, etc., should be protected from falling mortar and dirt. When possible these parts should be covered with a piece of leather, canvass, or tin. This will keep the machine in better working order and prolong its life.

All joints and working parts should be oiled in the morning before starting work.

Lubricating the Molds.—To prevent the moulds from sticking to the block, keep the moulds clean and free from rust; wipe the face of them at night with oil waste, and brush frequently with oil while in use. Or, a wash made of soap dissolved in water can be brushed on the face of the mould just before filling with concrete.

A solution of paraffin and gasoline applied to the moulds will also prevent them from sticking.

Laying Cement Blocks.—The mortar for laying cement blocks should be composed of 1 part Portland cement and 3 parts fine sharp sand, to which can be added a little lime putty, or hydrated lime, to render the mortar less "brittle" and cause it to work "smooth." The lime putty should be made several days before being required for use, so all particles of lime will be slaked.

The mortar can be colored if desired, as explained on page 78.

The blocks before being set in the wall should be wet, especially in hot, dry weather, so the dry block will not absorb all the moisture from the mortar, thus causing it to dry too fast and rendering it weak.

The mortar should be spread so as to give a uniform joint of about $\frac{1}{4}$ inch, and all perpendicular joints should be filled carefully with mortar. The joints can either be pointed as the work progresses, or they can be raked out about $\frac{3}{4}$ inch deep when the blocks are set, and after the walls are completed the entire work can then be washed down and the joints pointed.

A neat job of pointing adds much to the appearance of any wall, either stone or cement blocks.

Carrying Joist on Block Walls.—When building walls of cement blocks, provision must be made to carry the floor joists of the building.

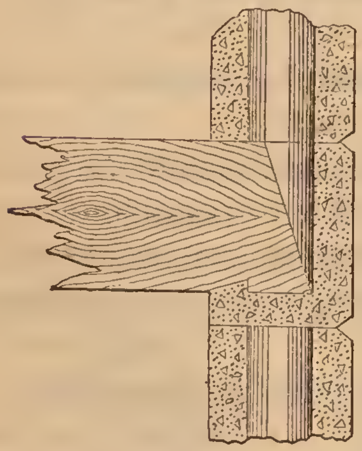

Fig. 149.—Block with Pocket for Joist.

Fig. 149 shows a method that has been used. Pockets are cast in the blocks and the joists inserted as shown. The ends of the joists should be cut to a bevel so they will readily be released and drop out in case of fire burning them off at one end.

Fig. 150 shows the joist supported by a wrought-iron joist hanger, several makes of which areon the market.

Fig. 151 shows a block with a box anchor cast in the block.

This is the Goetz joist box or anchor, and provides a pocket

for the joist and also anchors it to the wall as the joist is notched over a lug in the bottom of the box.

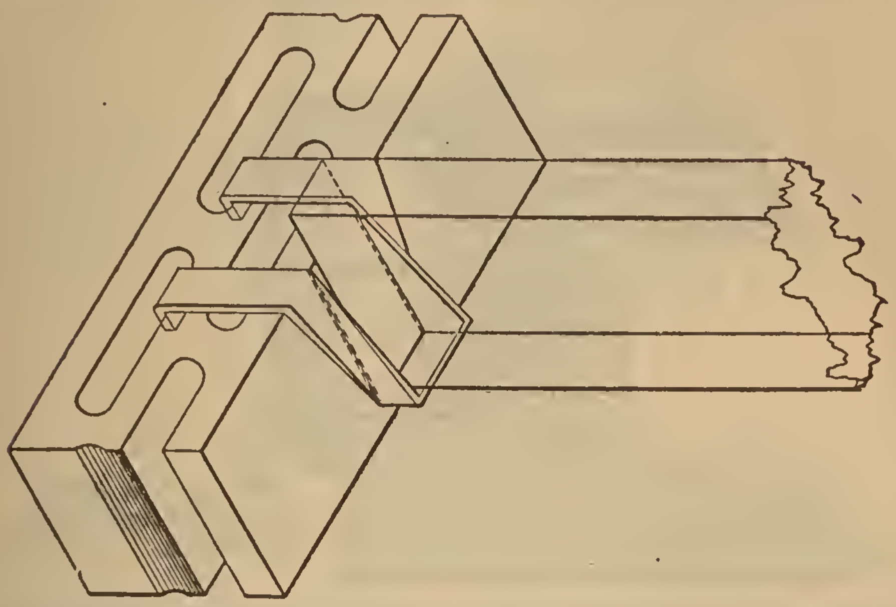

Fig. 150.—Use of Joist Hanger with Concrete Blocks.

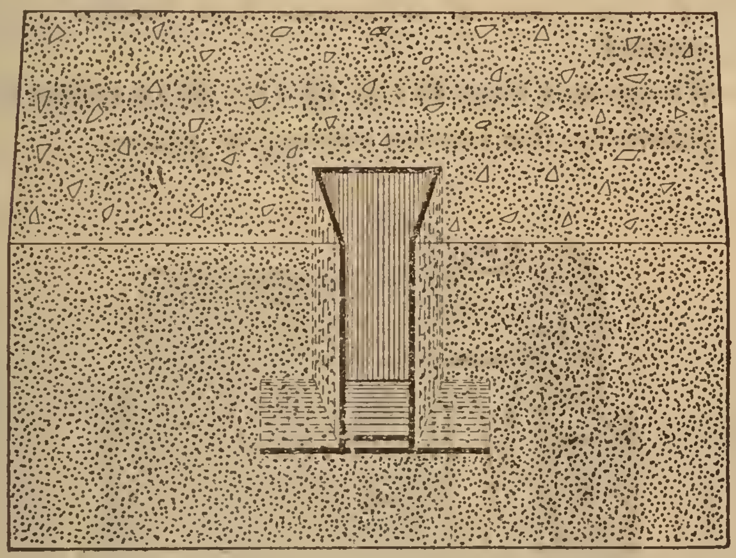

Fig. 151.—Joist Anchor Cast in Concrete Block.

Fastening Frames in Concrete Walls.—When making jamb-blocks or when building concrete walls around openings, provision must be made for securing the frame, nailing up the trim, etc.

Fig. 152 shows how blocks can be made for around window openings. Bolts can be put in the blocks as shown, when the blocks are made, letting the bolts project out far enough to receive and bolt fast the rough jamb as shown. If it is a solid

concrete wall the form must be made of the shape shown, and the bolts put in place as the concrete is deposited. Ordinary $\frac{1}{4}'' \times 6''$ carriage bolts are the best bolts to use.

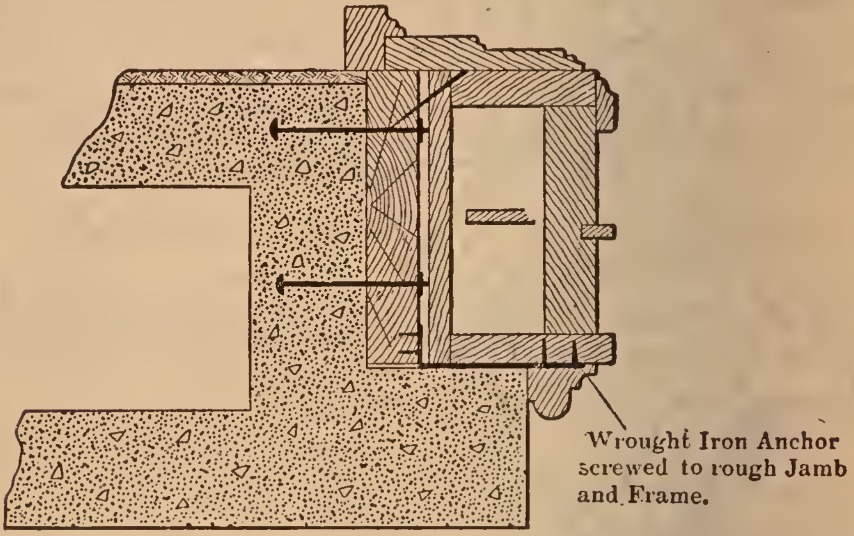

Fig. 152.—Method of Fastening Window Frames in Concrete Construction.

The frame and trim is anchored and nailed to the rough jamb as indicated.

If the bolts are not cast in the blocks when made they can be put in the joints as the blocks are set in place.

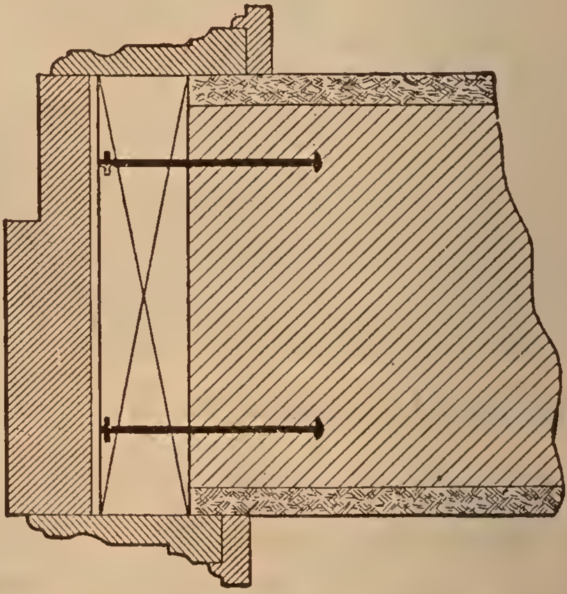

Fig. 153.—Wood Jamb Fastened with Bolts.

Figs. 153 and 154 show how a rough or false wood jamb can be bolted to a brick or concrete jamb and the door jamb and trim can then be nailed securely to the false jamb. By

toe-nailing the nails can nearly all be concealed. The bolts must be put in place as the walls are built.

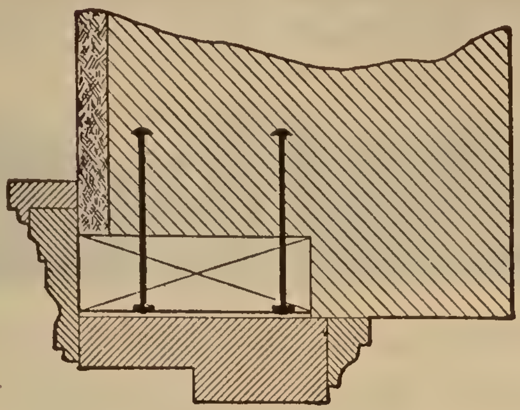

FIG. 154.—Wood Jamb Fastened with Bolts.

Special Nailing Blocks.—For nailing purposes, such as nailing base, trim, etc., cement blocks can be made with a dove-tail wooden block cast in the cement block, similar to the method of casting the anchor in the block as shown by Fig. 151, page 253.

If granulated furnace slag is used in place of sand for making the block nails can be driven in the block and will hold very well.

Special Moulds for Ornamental Cement Work.—The cement-block manufacturer should be able to make special

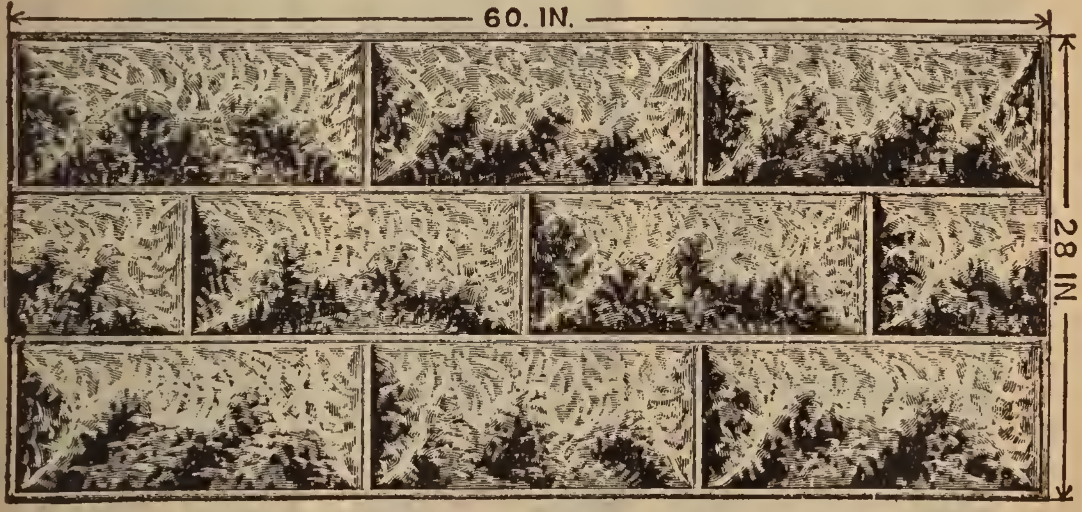

FIG. 155.—Sheet Metal Stamped Rock-face.

moulds to meet the requirements of the drawings of various architects, so that he will be able to produce any style or shape block desired by the architect.

For making special moulds for rock-face work sheets of stamped metal in imitation of rock-face, such as shown by

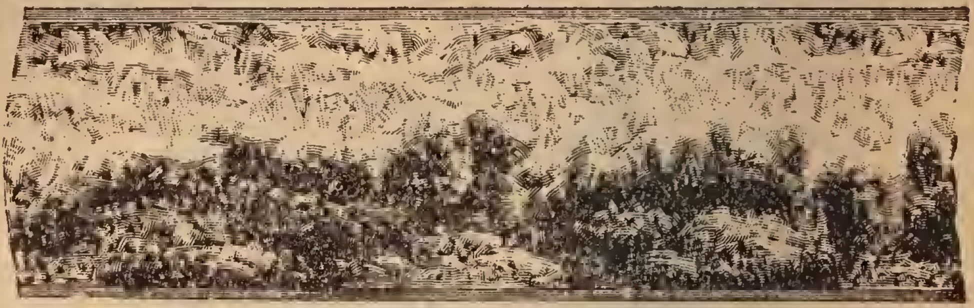

FIG. 156.—Continuous Rock-face in Sheet Metal.

Figs. 155 and 156, can be procured at little cost from any stamped metal manufacturer. This metal can be procured

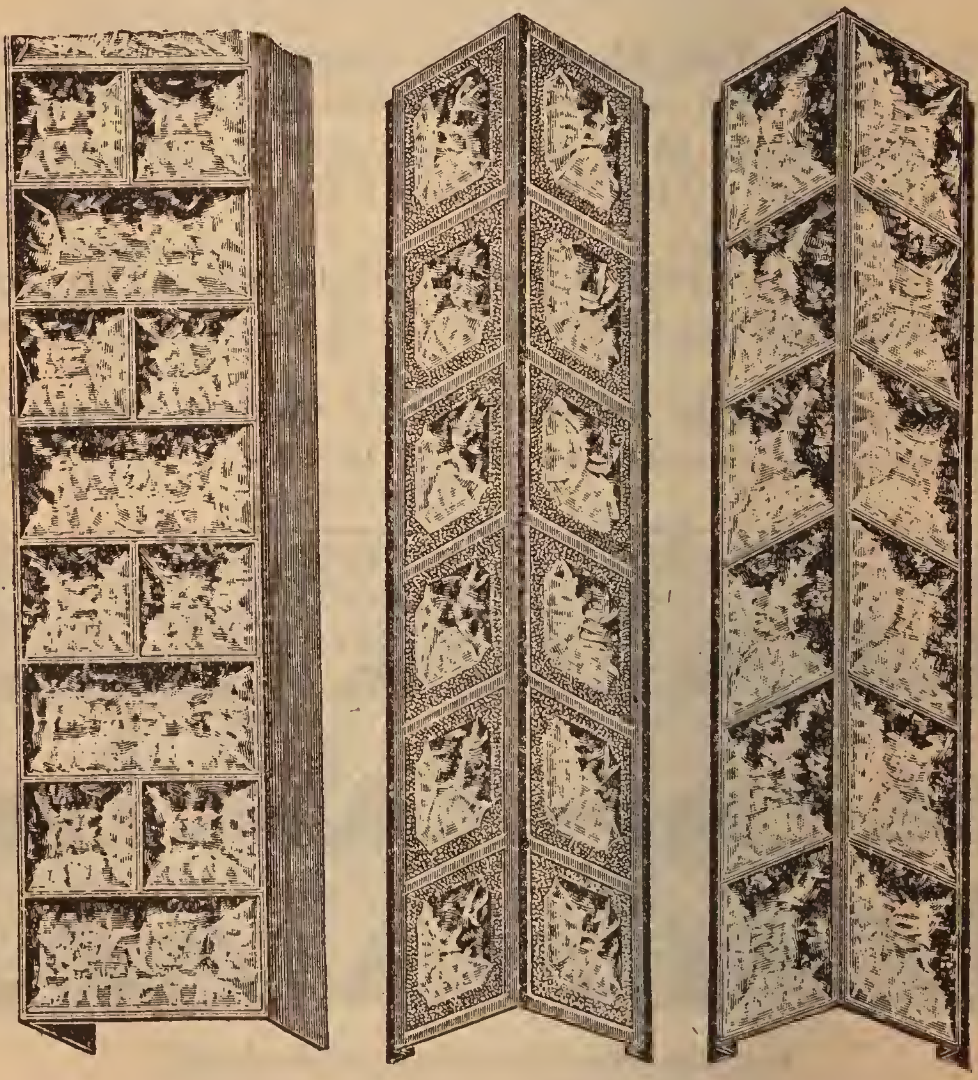

FIG. 157. FIG. 158. FIG. 159.
Sheet Metal Forms for Piers, etc.

in blocks of various sizes, and also in long lengths of 5 to 8 feet and of widths from 6 to 12 inches.

Similar stamped shapes can also be procured for use in making blocks for piers, porch columns, etc., as shown by Figs. 157–159.

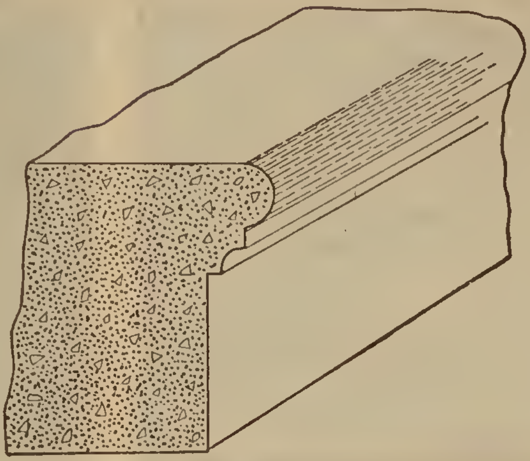

FIG. 160.—Step with Nosing.

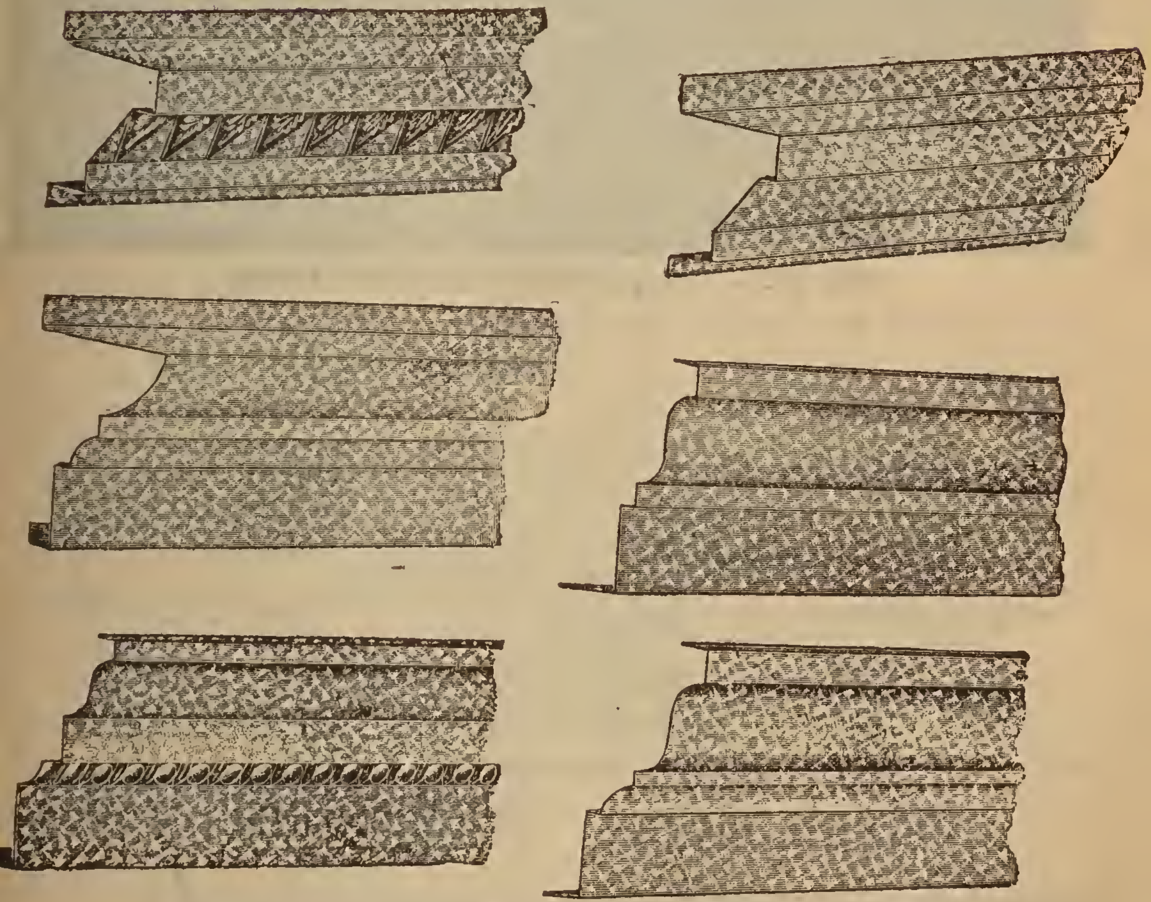

FIG. 161.—Sheet Metal Moulds for Belts, Cornices, etc.

Steps with nosing and bed-mould, as shown by Fig. 160, can be moulded in sheet metal forms which can be procured at a nominal cost.

Sheet metal bent and stamped to designs, such as shown

by Fig. 161, can be procured for moulding blocks for belt courses, cornices, etc. These metal shapes can be bought in

FIG. 162.—Stamped Metal Panels and Frieze.

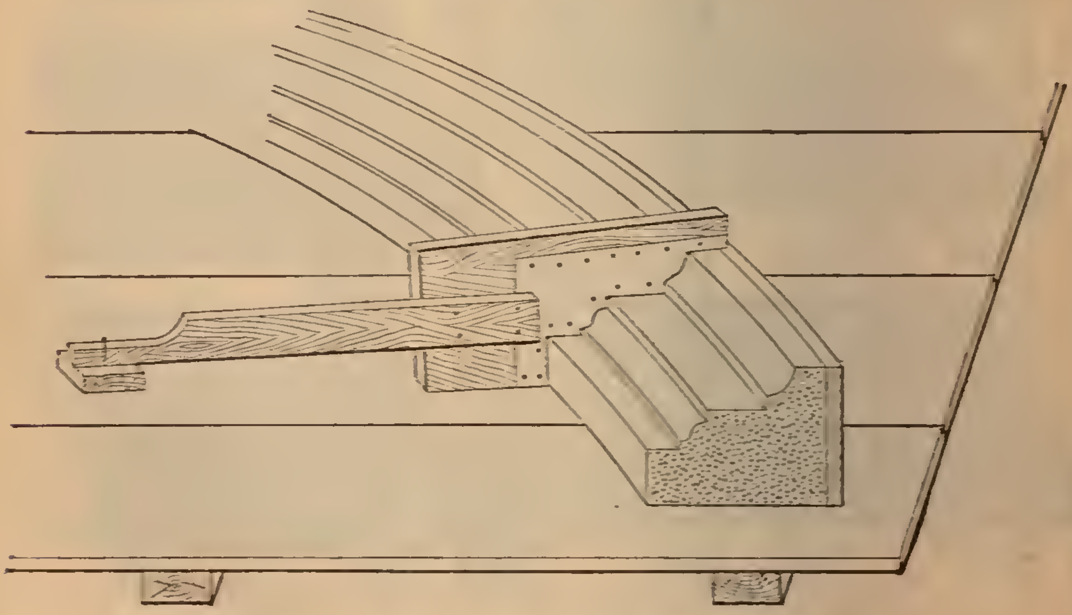

FIG. 163.—Running Circle Moulding.

lengths up to 8 feet, and in them the blocks can be made any length desired.

Straight mouldings can also be run with a mould, similar to

the method shown by Fig. 163. The moulding being run in long lengths and then jointed and cut while green into the lengths desired.

Stamped or spun circle mouldings can also be procured in sheet metal, and which makes good moulds for bases or tops of columns, etc.

Spum ballusters can be cut apart and used for moulds for making cement ballusters, and for ornamental panels, friezes, etc., there is a variety of designs made in stamped metal, such as shown in Fig. 162, which makes very good moulds for ornamental cement work.

Circle mouldings can also be run with a mould, as shown by Fig. 163. The mould is set up to the desired radius, the moulding run, and then cut into the lengths desired.

Glue or Gelatine Moulds.—Elaborate designs can be reproduced in cement by casting in glue moulds. The glue is prepared as explained on page 397, or steep about 12 pounds of glue over night and then heat until it is a fluid, and then add about 3 pounds of molasses well mixed in by stirring.

Oil the model or pattern so the glue will not stick, put it in a vessel or box large enough, so the top of the pattern will be below the top of the box and then pour in the glue mixture until the pattern is entirely covered.

When cold take the entire mass from the box and take the mould from around the pattern by cutting the mould into several pieces.

The glue should then be oiled to prevent sticking and the different pieces put in place and an opening cut through which to pour the cement; after being put in place in the box the interior of the mould can then be run full of cement, thus reproducing in cement the design and shape of the original.

To prevent wet cement from dissolving the glue mould give the mould a coat of a solution of 1 part bichromate of potash and 10 parts water. This will harden the face of the mould so the wet cement will not affect it, but the glue thus hardened cannot be remelted again.

Several coats of paraffin oil will also render the glue mould waterproof.

Another method is to coat the moulds with a solution of alum and water, as much alum as the water will dissolve.

If the original pattern for making a glue mould is of plaster of Paris or cement it should be given several coats of shellac

before the glue is poured on it, to prevent the glue from sticking to the model.

Rubber Moulds.—Rubber moulds have been made and used to some little extent for making ornamental blocks, and give very good results, but are quite expensive.

A block with a corrugated face, as shown by Fig. 164, can be made by using the corrugated rubber matting that can be bought in nearly any furniture store, for a face mould Various designs in this rubber can be purchased, such as diamonds, squares, etc. The rubber matting is cut to the desired

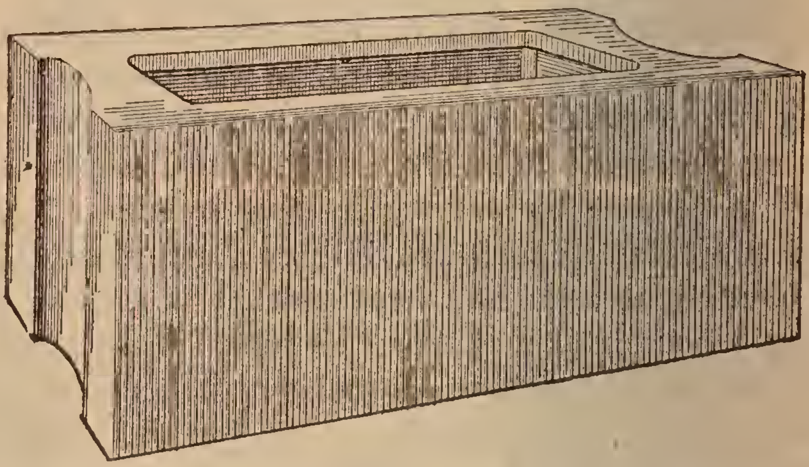

FIG. 164.—Block Faced with Rubber Mould.

shape and put against a plain face mould for the face of the block, and the block is then made in the usual way.

When the moulds are taken from around the block the rubber can then be peeled off, leaving the face as shown.

Paper Moulds.—Stamped patterns in papier maché, lincrusta, etc., when coated with shellac, can be used in the same manner as described above, and very neat designs can be reproduced.

Brass and Glass Moulds.—Brass and glass moulds are now being manufactured and sold, and are very easy manipulated, their surface being so smooth the blocks do not stick.

Casting Cement Stone or Blocks.—Artificial stone-making, or making artificial stone by casting in moistened sand, is described by W. P. Butler, who invented this process, as follows:

"OPENING CASTING.—The first step in the process is to make a wooden pattern of the stone to be made. This pattern or model is made of the exact size of the stone desired, and it may be made in one or in several pieces. The size and style

of the block usually determines the method to use in the casting of it.

"The most common method of casting is that of casting on the floor, or 'open casting,' as it is commonly called. Nearly all large stones as well as small ones are cast this way. The method is illustrated in Fig. 165, where the moulding compound is shown as spread out upon the floor. The pattern is imbedded solidly upon the compound (which for brevity we will call the sand) which is then packed solidly around it and built up until it is fully imbedded in the same manner that a pattern is set in the sand in a foundry. To remove the pattern from the sand it should be lightly tapped, so as to loosen it without noticeably enlarging the mould, from which it should then be withdrawn with the greatest care so as not to break down the edges.

"If, on examination, the surfaces of the mould are not perfectly smooth, or if any edge is broken down, or if any detail

Fig. 165.—Open Casting on Floor.

is imperfect or damaged, it may be 'touched up' or repaired with the moulder's tools which it is necessary to have.

"One perfect mould having been made, as many others as are desired can be made in like manner from the same pattern. A competent moulder can make from five to fifty moulds in a day, acocrding to the difficulty or size of each. If the pattern has no projecting parts which would prevent its being withdrawn from the sand, it may best be made in one piece, but if there are projecting details or undercuts on the pattern, then it must be made in two or more pieces so as to make it possible to withdraw it from the sand without breaking down the mould. This necessitates not only good workmanship on the part of the patternmaker, but a thorough knowledge on his part of the necessities of the moulding process.

"The removal from the sand of a pattern of two or more pieces is done in the same manner as though there was but one piece, but it requires more time and care.

"In Fig. 166 there is shown a three-piece pattern imbedded

in the sand at *A*. At *B* the main part of the pattern and one of the side pieces is shown as withdrawn, while one side piece is still in the sand. The cast of the block is shown at *C*.

"COMPARTMENT CASTING.—If the block to be cast is for a cornice, belt-course, water-table, or any similar purpose where there is an ornamental or moulded face, with the other sides

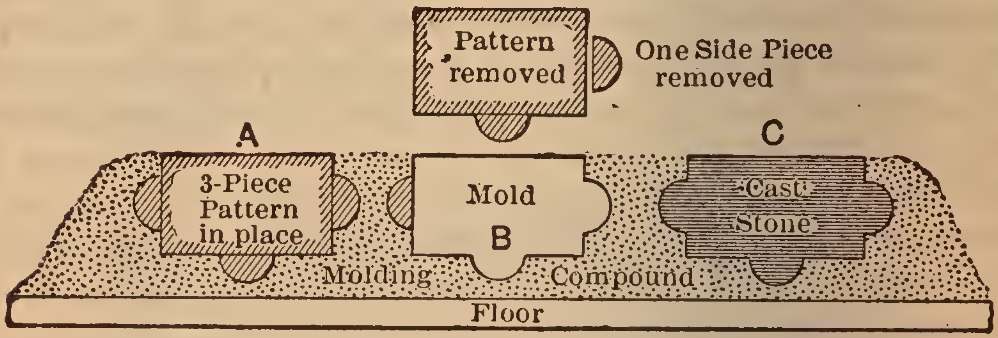

FIG. 166.—Removing Patterns in Open Casting.

plain, a better and more rapid method of casting is to fasten two planks on edge, and parallel with each other, as shown at *AA* in the following Fig. 167, with partitions, *P*, fastened between the planks at proper distances, forming a series of compartments in each of which is to be cast a stone. The

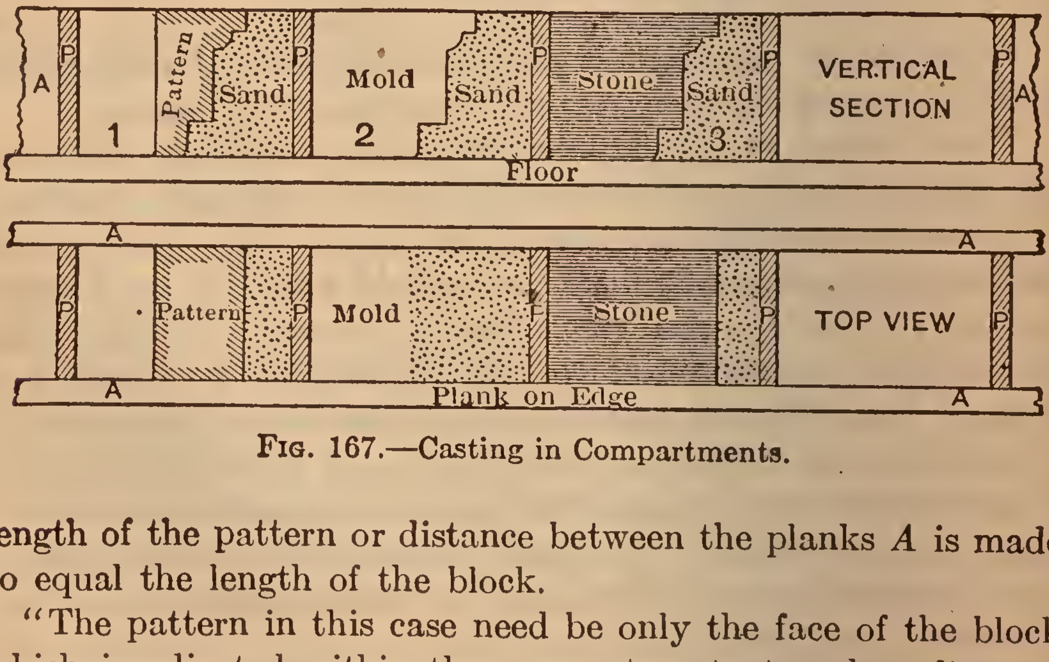

FIG. 167.—Casting in Compartments.

length of the pattern or distance between the planks *A* is made to equal the length of the block.

"The pattern in this case need be only the face of the block which is adjusted within the compartment at such a distance from the partition back of it as to give the proper width to the block. Then in the space in front of the pattern, solidly tamp the sand, as shown in the drawing at 1.

"Next loosen the pattern and draw it away from the sand, which retains the design of the face, which is shown at 2. This process is repeated in the several compartments, and the moulds are then filled as at 3. By this method a minimum of time is required and blocks are formed much more rapidly than when moulded in a bed of material on the floor.

"Casting in Open-end Flasks.—The method of casting illustrated by Fig. 168 will prove to be the best in many cases, especially where it is desired to pack the moulding compound vertically on the face of the pattern. In this figure *A* represents, in section, a box or collapsible 'flask' open at the top and bottom. Within the flask and at the proper distance from the bottom is fastened the pattern or face-plate *B*.

"Over and upon the top of the pattern tamp the sand, as shown at *E*, and then fasten over this the cover *C* to hold the

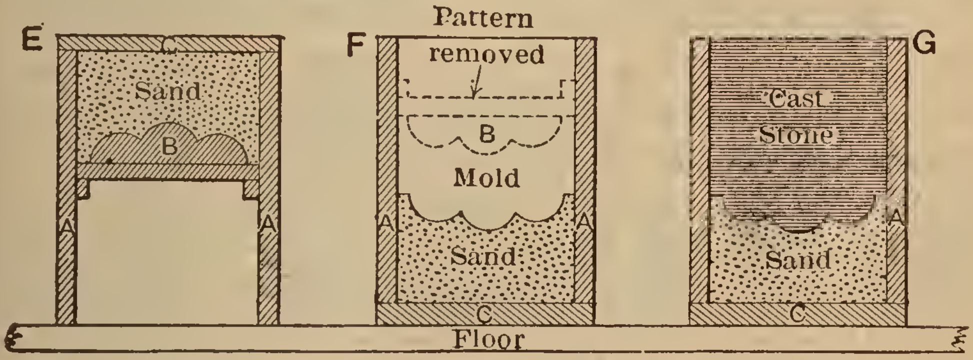

Fig. 168.—Casting in Open-end Flasks.

sand in position while the flask is being turned over, as shown at *F*. Next loosen and remove the pattern as shown, leaving the mould ready for the cast as shown at *G*, wherein the face of the block alone is in the sand. When the cement is hardened the flask is loosened and removed.

"Casting in Closed Flasks.—Many pieces, such as balusters, balls, or similar turned forms, or forms which are symmetrical on all sides, must be cast in closed boxes or flasks, as shown in Fig. 169.

"The pattern of the baluster is, in the case shown, made in two pieces which are imbedded in the lower and upper halves of the flask.* The patterns are then withdrawn and the two halves of the flask are carefully locked together in the position

* Spun metal balusters or stamped metal ornaments make good patterns for making the mould, and one pattern will make any number of moulds.—Author.

shown at *C*. The cast is then made by pouring the liquid cement through the opening in the end of the flask. A great variety of the finest ornamental work is cast in this manner. There are other special methods of casting cement stone, but the ones illustrated are those most commonly used in ordinary practice.

"In all cases the cement and powdered stone, in the proportions of one of cement to three of stone dust, are mixed with water until of the consistency of thick gravy, and then carefully poured into the mould, using a pouring board or pipe to guide the stream and prevent its tearing the sand up. The mass is then allowed to set and harden for about a week before it is removed from the mould. This protection of the cement in the moistened mould prevents the cracking or checking of the surface. When the stone is fully dried out the surface

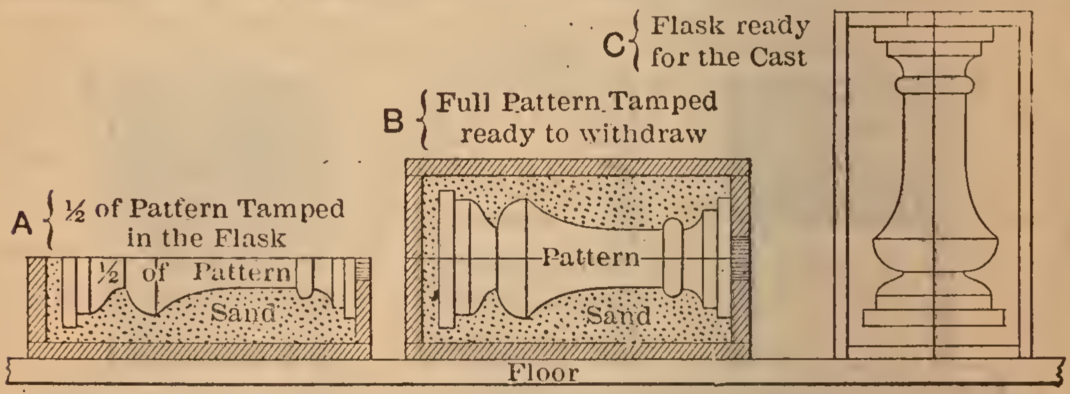

Fig. 169.—Casting in Closed Flasks.

is brushed off with a wire brush to remove the surplus sand, and, if a tooled appearance is desired, the surface can be gone over with tools and then the block cannot be distinguished from one carved from the natural stone."

Pouring the Cement.—The mould or series of moulds having been prepared, the stone-making material should be mixed of proper proportions and consistency for pouring and should then be kept agitated or stirred so as to keep it uniform until it is poured into the moulds. The mixture should not be allowed to stand for over 15 or 20 minutes before being used, nor should the moulds remain unfilled any longer than is necessary, as they dry out and become more fragile.

The process of pouring requires much care and expedition in order to produce the best results. If the cement is to be poured over the face of the mould it should not be poured directly on the sand but on to a thin "pouring board," which

is used to break the force of the falling stream of cement, to distribute it more gently over the face of the mould, and to prevent the tearing up or breaking down of the sand.

The board should be held and guided by the one in charge of the casting, while others bring and pour the cement. Here again care must be used, for in the pouring there must be no interruption in the flow of material. One pail-carrier (if the pouring is done from pails) must begin to pour as soon as the former one has finished. If there is even a brief interval in the flow there will be a "set-line," or crease on the face of the block.

If the whole face of the mould is flooded first then there can be no set-lines and the filling of the mould may be done more slowly. This is important where the mould is very large and the filling of it a slower process.

In some large plants the pouring is done from a ladle, carried on a traveling crane, in which are rotary paddles for the purpose of keeping the mixture stirred and of uniform consistency. Where the pouring is done into deep molds or into closed flasks, as in Fig. 169, where the fall of the stream would tear up the sand, it should be done through a funnel and pipe with a T outlet, which breaks the force of the fall of the cement and distributes it without danger to the mold.

As the absorption of moisture from the stone into the sand causes a decrease in the volume of the mixture in tne mould and causes it to settle at the top, it is usually necessary to add a litle material to fill the depression before the mixture has set.

Materials.—There is a wider latitude in the selection of the material to be used on account of the variety and size of the product.

In the making of all small blocks, and the facings of larger ones, powdered stone * (stone dust) is often used. If this material is as cheap as other aggregates, then the entire mass may best be made of it.

If the block is one of large size, and if powdered stone is more expensive than sand and broken stone, then these coarser aggregates may best be used for the body or back of the block after the richer and finer material has been poured over the face of the block.

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* Recent tests show that cement and stone dust make as strong blocks as cement and sand.—Author.

Settling of the Aggregates.—Persons unfamiliar with the casting process often express fear that the heavier aggregates will settle to the bottom of the mould, thus making a stone of unequal texture and strength. If the mixture is made very thin and contains heavy matter, such as coarse gravel or stone, that portion would of course settle through the mass to the bottom. But if the mass is made of fine material, such as stone dust, there is never any settling.

If chunks of broken blocks or stone are imbedded in the mass, it must be of such thickness or consistency as to support them. The face of the mould having been covered with thin and richer matter the backing or body of the mass may be much thicker and there will be no settling.

SPECIFICATIONS FOR HOLLOW BLOCKS OF THE NORTHWESTERN CEMENT-PRODUCTS ASSOCIATION.

The Northwestern Cement-Products Association, at its annual meteing, held at Minneapolis, January 17, 18, and 19, 1906, adopted standard specifications for hollow blocks as follows:

SAND.—Such material as will pass through a screen $\frac{1}{4}$-inch mesh and is retained in screen having No. 40 mesh. This applies to river sand, bank sand, or screenings from a stone-crusher.

GRAVEL.—Such stone or rock, obtained either from a bank or river, of such size as is retained in a screen having $\frac{1}{4}$-inch mesh.

CRUSHED STONE.—Such stone from a crusher as is retained in a $\frac{1}{4}$-inch screen.

BANK GRAVEL.—Such material as is obtained from a pit or river containing both sand and gravel.

AGGREGATE.—Any material, such as broken stone, gravel, or such fragments used with cement and sand mortar in making concrete for the purpose of reducing the cost and adding to the strength.

VOIDS.—The space existing between particles of sand, crushed stone, or materials of which an aggregate is composed.

CEMENT.—Any American or Portland cement which will pass the tests required by the American Society for Testing Materials.

Quality of Sand.—Sand suitable for concrete work must not be finer than the above described, must be sharp and gritty, not soft or loamy, must be free from loam, or other foreign material, and must not contain any perceptible amount of clay or other soluble matter. Some authorities conceded that clay to the extent of 10 per cent in sand or gravel is not harmful, but this committee is of the opinion that any perceptible amount of clay is unsafe. Crushed stone must be reasonably free from dust and must be retained on the same size screen as bank sand—viz., ¼-inch. Gravel or crushed stone must be free from loam, dust, or other foreign material, and must contain no soft or rotten stone.

Determination of Amount of Cement to be Used with Aggregate.—A theoretically correct concrete should consist of sand and gravel, or crushed stone, or a combination of them, containing an amount of cement equal to the voids, in such combination. In other words, interstices should be filled with cement.

To state this in another way, if the concrete is made up of sand and gravel, such proportion of cement should be used with the sand as is equal to the voids in the sand, and such quantity of this resulting mortar of sand and cement should be used with the crushed stone or gravel as will fill all voids in the crushed stone or gravel.

Restating this in a few words, the cement should fill the voids in the sand, and the resulting mortar should fill the voids in the aggregate.

Determination of Voids.—To determine the voids in the sand or the material to be used as an aggregate, what is known as the "water test" is employed. In preparing for this test, the sand or gravel must be perfectly dry. Sand has greater volume when wet.

A receptacle holding a known amount, such as a quart jar, is filled with the material to be tested—sand, for example—and into this receptacle is poured as much water as the sand or other material will absorb. The water should be measured. The amount of water absorbed indicates the voids, and also indicates the exact amount of cement which it is necessary to use in order to produce a solid concrete.

In making hollow blocks, if no gravel or other coarse aggregate is used, the result of this test should give the proportions of sand and cement to be used in block manufacture. Average

sand will absorb 25 to 35 per cent of water, indicating from 25 to 35 per cent of voids; also indicating that the proportion to 1 part of cement to from 3 to 5 parts of sand are required to make a solid block.

The proper selection of sand and aggregate material is important. Care should be taken that the particles vary so in size as to reduce the voids to the smallest amount possible. With this careful selection the amount of cement required to produce good work is greatly reduced.

Provided that in defining the proportions of cement we mean that a given measure of cement is one portion and that multiples of that measure of aggregates as properly combined under the water test shall determine the proportion. If found under the test that 5 parts crushed stone or gravel will take 3 portions of sand to fill the voids without increasing the bulk, and that 1 portion of cement shallfill the remaining voids, this proportion shall be a 1 to 5 mixture.

Mixing.—After the materials are selected they should be mixed together dry until thoroughly incorporated, or, in other words, until the mass is of an absolutely uniform color. Water should then be applied and the thorough mixture repeated. The amount of water should be in all cases as great as possible without causing the materials to stick to the moulds when the stone is removed.

A little more care in the treatment of the face plates of any machine will enable the manufacturer to use a wetter concrete than is usually employed. Only such size batches should be mixed at one time as can be used up within thirty minutes from the time the water has been added.

Manufacturing.—The concrete should be placed in the mould in small quantities, and tamping should begin immediately upon the placing of the first shovelful and continue until the mould is full. The material should be tamped with a tamper having a small face, and short, quick, sharp blows should be struck.

In faced blocks the face should be composed of 2 parts sand and 1 part cement, the same being mixed in the manner described above.

Owing, however, to the excess of cement used in facing, and owing further to the fact that the cement is what makes concrete sticky, the facing cannot be used as wet as the balance of the block is made. Great care should be taken to tamp

the concrete thoroughly into the facing, so as to unite the two into one solid stone.

In the wet process the amount of water is such as will produce a plastic or flowing condition in the concrete, but not enough to wash the cement from the other material. When placing the material in the moulds the entire mould is filled with one pouring.

No stone having transverse ties or webs cracked should be used or even allowed to cure. Should a slight crack occur in moving the green stone throw the material back and make it over. In no case use a cracked stone in a building.

Curing.—All stone made by the medium wet or medium dry process should be made under cover and kept under cover for at least ten days, protected from the dry currents of air. If shed room is not available to store a ten days' output the blocks should be carried out after the initial set has taken place and covered with canvas, hay, or other covering that will retain moisture and at the same time keep the dry air from circulating around the block. Under no circumstances should blocks be made under the direct rays of the sun, nor should blocks made by this process be exposed to either sunshine or dry winds while curing.

The blocks should be gently sprinkled as soon as possible after making—that is, just as soon as the cement has set sufficiently that it will not wash. Blocks should be kept wet from ten days to two weeks, and should never be removed from the yard for the purpose of using in a building until they are from thirty to sixty days old. This is very important. A green block will surely crack in the building on account of shrinkage.

Laying.—In laying cement stone a soft mortar, composed of $\frac{1}{2}$ cement-mortar and $\frac{1}{2}$ lime-mortar should be used. This mortar should be made with fine sand free from stone, and should be buttered on the ends of the stone before laying. The stone should be laid in the mortar and worked down. Do not leave end joints open until after the building is completed, because when the end joints are filled at this time shrinkage in mortar is liable to loosen it, causing the mortar to fall out, leaving openings through the wall.

The spreading of mortar is very important, because if mortar is unevenly spread so that it is thicker under one portion of the stone than under the other a leverage is created, which,

under the weight of the wall, is liable to produce a crack in stone.

Coloring.—In using coloring matter with concrete the color should always be mixed with the cement dry before any sand or water is added. This mixing should be thorough, so that the mixture is uniform in color. After this mixing the combination is treated in the same way as clear cement.

STANDARD SPECIFICATIONS FOR BLOCKS.

Rules and Regulations for Blockmakers, as Revised, Corrected, and Adopted by the National Association of Cement Users at their Convention, 1908.

Concrete hollow blocks made in accordance with the following specifications, and meeting the requirements thereof, may be used in building construction, subject to the usual form of approval required of other materials of construction by the Bureau of Building Inspection:

1. Cement.—The cement used in making sand blocks shall be Portland cement, capable of passing the requirements as set forth in the "Standard Specifications for Cement," by the American Society for Testing Materials.

2. Sand.—The sand used shall be suitable siliceous material, passing the one-fourth inch mesh sieve, clean, gritty, and free from impurities.

3. Stone or Coarse Aggregate.—This material shall be clean broken stone, free from dust, or clean screened gravel passing the three-quarter ($\frac{3}{4}$) inch, and refused by the one-quarter ($\frac{1}{4}$) inch, mesh sieve.

4. Unit of Measurement.—The barrel of Portland cement shall weigh 380 pounds net, either in barrels or sub-divisions thereof, made up of cloth or paper bags, and a cubic foot of cement shall be called not to exceed 100 pounds or the equivalent of 3.8 cubic feet per barrel. Cement shall be gauged or measured either in the original package as received from the manufacturer, or may be weighed and so proportioned; but under no circumstances shall it be measured loose in bulk.

5. Proportions.—For exposed exterior or bearing walls: (*a*) Concrete hollow blocks, machine made, using semi-wet concrete or mortar shall contain one (1) part cement, not to exceed three (3) parts sand, and not to exceed four (4) parts

stone, of the character and size before stipulated. When the stone shall be omitted, the proportions of sand shall not be increased, unless it can be demonstrated that the percentage of voids and tests of absorption and strength, allow in each case of greater proportions, with equally good results. (*b*) When said blocks are made of slush concrete, in individual moulds and allowed to harden undisturbed in same before removal, the proportions may be one (1) part cement to not exceed three (3) parts sand and five (5) parts stone, but in this case also, if the stone be omitted, the proportion of sand shall not be increased.

6. MIXING.—Thorough and vigorous mixing is of the utmost importance.

(*a*) *Hand Mixing.*—The cement and sand in correct proportions shall be first perfectly mixed dry, the water shall then be added carefully and slowly in propor proportions, and thoroughly worked into and throughout the resultant mortar; the moistened gravel or broken stone shall then be added, eihter by spreading same uniformly over the mortar, or spreading the mortar uniformly over the stones, and then the whole mass shall be vigorously mixed together until the coarse aggregate is thoroughly incorporated with and distributed throughout the mortar.

(*b*) *Mechanical Mixing.*—Preference shall be given to mechanical mixers of suitable design and adapted to the particular work required of them; the sand and cement, or sand and cement and moistened stone shall, however, be first thoroughly mixed before the addition of water, and then continued until the water is uniformly distributed or incorporated with the mortar or concrete: Provided, however, that when making slush or wet concrete (such as will quake or flow) this procedure may be varied with the consent of the Bureau of Building Inspection, architect or engineer in charge.

7. MOULDING.—Due care shall be used to secure density and uniformity in the blocks by tamping or other suitable means of compression. Tamped blocks shall not be finished by simply striking off with a straight edge, but, after striking off, the top surfaces shall be trowelled or otherwise finished to secure density and a sharp and true arris.

8. CURING.—Every precaution shall be taken to prevent the drying out of the blocks during their initial set and first hardening. A sufficiency of water shall first be used in the

mixing to perfect the crystallization of the cement, and, after moulding, the blocks shall be carefully protected from wind currents, sunlight, dry heat or freezing, for at least five (5) days, during which time additional moisture shall be supplied by approved methods, and occasionally thereafter until ready for use.

9. AGEING.—Concrete hollow blocks in which the ratio of cement to sand be one-third ($\frac{1}{3}$) (one part cement to three parts sand), shall not be used in the construction of any building in the (City) of ——— (Town) of ——— until they have attained the age of not less than three (3) weeks.

Concrete hollow blocks in which the ratio of cement to sand be one-half ($\frac{1}{2}$) (one part cement to two parts sand), may be used in construction at the age of two (2) weeks, with the special consent of the Bureau of Building Inspection and the architect or engineer in charge.

Special blocks of rich composition, required for closures, may be used at the age of seven (7) days with the special consent of the same authorities.

The time herein named is conditional, however, upon maintaining proper conditions of exposure during the curing period.

10. MARKING.—All concrete blocks shall be marked for purposes of identification, showing name of manufacturer or brand, date (day, month, and year) made, and composition or proportions used, as, for example, 1:3:5, meaning one cement, three sand, and five stone.

11. THICKNESS OF WALLS.—The thickness of bearing walls for any building where concrete hollow blocks are used, may be ten (10) per cent less than is required by law for brick walls. For curtain walls, or partition walls, the requirements shall be the same as in the use of hollow tile, terra-cotta, or plaster blocks.

12. PARTY WALLS.—Hollow concrete blocks shall not be permitted in the construction of party walls, except when filled solid.

13. WALLS, LAYING OF.—Where the face only is of hollow concrete block, and the backing is of brick, the facing of hollow block must be strongly bonded to the brick either with headers projecting four (4) inches into the brickwork, every fourth course being a heading course, or with approved ties; no brick backing to be less than eight (8) inches. Where the walls are made entirely of concrete blocks, but where said blocks

have not the same width as the wall, every fifth course shall extend through the wall, forming a secure bond, when not otherwise sufficiently bonded. All walls, where blocks are used, shall be laid up with Portland cement mortar.

14. Girders or Joists.—Wherever girders or joists rest upon walls so that there is a concentrated load on the block of over two (2) tons, the block supporting the girder or joists must be made solid for at least eight (8) inches from the inside face. Where such concentrated load shall exceed five (5) tons, the blocks for at least three courses below, and for a distance extending at least eighteen (18) inches, each side of said girder, shall be made solid for at least eight (8) inches from the inside face. Wherever walls are decreased in thickness, the top course of the thicker wall shall afford a full solid bearing for the webs or walls of the course of blocks above.

15. Limit of Loading.—No wall, nor any part thereof, composed of concrete hollow blocks, shall be loaded to an excess of eight (8) tons per superficial foot of the area of such blocks, including the weight of the wall, and no blocks shall be used in bearing walls that have an average crushing at less than 1000 pounds per sq. in. of area, at the age of twenty-eight (28) days; no deduction to be made in figuring the area for the hollow spaces.

16. Sills and Lintels.—Concrete sills and lintels shall be reinforced by iron or steel rods in a manner satisfactory to the Bureau of Building Inspection, and the architect or engineer in charge, and any lintels spanning over four feet six inches shall rest on block solid for at least eight inches from the face next the opening and for at least three courses below the bottom of the lintel.

17. Hollow Space.—The hollow space in building blocks, used in bearing walls, shall not exceed the percentage given in the following table for different height walls, and in no case shall the walls or webs of the block be less in thickness than one fourth their height. The figures given in the table represent the percentage of such hollow space for different height walls:

Stories.	1st.	2d.	3d.	4th.	5th.	6th.
1 and 2	33	33				
3 and 4	25	33	33	33		
5 and 6	20	25	25	33	33	33

18. Application for Use.—Before any such material be used in buildings, an application for its use and for a test of the same must be filed with the Bureau of Building Inspection. In the absence of such a bureau the application shall be filed with the chief of any department having such matters in charge. A description of the material and a brief outline of its manufacture and proportions used must be embodied in the application. The name of the firm or corporation, and the responsible officers thereof, shall also be given, and changes in same thereafter promptly reported.

19. Preliminary Test.—No hollow concrete blocks shall be used in the construction of any building unless the maker of said blocks has submitted his product to the full tests required herein, and placed on file with the Bureau of Building Inspection, or other duly authorized official, a certificate from a reliable testing laboratory, showing that representative samples have been tested and successfully passed all requirements hereof, and giving in detail the results of the tests made.

No concrete blocks shall be used in the construction of any building until they have been inspected and approved, or, if required, until representative samples be tested and found satisfactory. The results of all tests, made whether satisfactory or not, shall be placed on file in the Bureau of Building Inspection. These records shall be open to inspection upon application, but need not necessarily be published.

20. Additional Tests.—The manufacturer and user of such hollow concrete blocks, or either of them, shall, at any and all times, have made such tests of the cements used in making such blocks, or such further tests of the completed blocks, or of each of these, at their own expense, and under the supervision of the Bureau of Building Inspection, as the chief of said bureau shall require.

In case the result of tests made under this condition should show that the standard of these regulations is not maintained, the certificate of approval issued to the manufacturer of said blocks will at once be suspended or revoked.

21. Certificate of Approval.—Following the application called for in clause No. 18, and upon the satisfactory conclusion of the tests called for, a certificate of approval shall be issued to the maker of the blocks by the Bureau of Building Inspection. This certificate of approval will not remain in

force for more than four months, unless there be filed with the Bureau of Building Inspection, at least once every four months following, a certificate from some reliable physical testing laboratory showing that the average of at least three (3) specimens tested for compression, and at least three (3) specimens tested for transverse strength, comply with the requirements herein set forth. The said samples to be selected by a building inspector, or by the laboratory, from blocks actually going into construction work.

22. Test Requirements.—Concrete hollow blocks must be subjected to the following tests: Transverse, compression, and absorption, and may be subjected to the freezing and fire tests, but the expense of conducting the freezing and fire tests will not be imposed upon the manufacturer of said blocks.

The test samples must represent the ordinary commercial product, of the regular size and shape used in construction. The samples may be tested as soon as desired by the applicant, but in no case later than sixty days after manufacture.

Transverse Test.—The modulus of rupture for concrete blocks at 28 days must average one hundred and fifty, and must not fall below one hundred in any case.

Compression Test.—The ultimate compressive strength at 28 days must average one thousand (1000) pounds per square inch, and must not fall below seven hundred in any case.

Absorption Test.—The percentage of absorption (being the weight of water absorbed, divided by the weight of the dry sample) must not average higher than 15 per cent, and must not exceed 22 per cent in any case.

23. Condemned Block.—Any and all blocks, samples of which on being tested under the direction of the Bureau of Building Inspection, fail to stand at twenty-eight (28) days the tests required by this regulation, shall be marked condemned by the manufacturer or user and shall be destroyed.

24. Cement Brick.—Cement brick may be used, as a substitute for clay brick. They shall be made of one part cement to not exceeding four parts clean sharp sand, or one part cement to not exceeding three parts clean sharp sand and three parts broken stone or gravel passing the one-half inch and refused

by the one-quarter inch mesh sieve. In all other respects, cement brick must conform to the requirements of the foregoing specifications.

Building Regulations of Concrete Blocks.—The city of Philadelphia has recently adopted rules and regulations regarding the manufacture and use of hollow concrete blocks which are based on an exhaustive series of tests made in the laboratories of Henry S. Spackman Engineering Co., on blocks selected at random from the yards of the various makers in Philadelphia, and for the purpose of comparison, similar tests were made on building-brick and solid concrete cubes, the bricks being tested after being built into piers of similar size with the concrete blocks.

Tests were also made in the laboratories of the City of Philadelphia, and as a result of this investigation the building laws of Philadelphia were modified, the new regulations printed below being substituted for those previously in force, which we think will in time form a model for other cities, as they have been carefully studied from every standpoint, representing the views of the Bureau of Building Inspectors, the Philadelphia Association of the Cement Block Manufacturers, and the testing laboratories of the Henry S. Spackman Engineering Co., and were only adopted after having been subjected to severe criticism and general discussion by all parties interested in their formulation. They should therefore be the most scientifically constructed of any yet prepared, and, while in some details they do not fit all conditions, it is certain that they will insure safe and durable structures. The regulations are as follows:

Rules and Regulations Covering the Manufacture and Use of Hollow Concrete Building-blocks in the City of Philadelphia.—1. Hollow concrete building-blocks may be used for building six stories or less in height, where said use is approved by the Bureau of Building Inspection, provided, however, that such blocks shall be composed of at least one (1) part of standard Portland cement and not to exceed five (5) parts of clean, coarse, sharp sand or gravel, or a mixture of at least one part Portland cement to five (5) parts of crushed rock or other suitable aggregate. Provided, further, that this section shall not permit the use of hollow blocks in party walls. Said party walls must be built solid.

2. All material to be of such fineness as to pass a half-inch

ring and be free from dirt or foreign matter. The material composing such blocks shall be properly mixed and manipulated, and the hollow space in said blocks shall not exceed the percentage given in the following table for different height of walls, and in no case shall the walls or webs of the block be less in thickness than one-fourth of the height. The figures given in the table represent the percentage of such hollow space for different height walls:

Stories.	1st.	2d	3d.	4th.	5th.	6th
1 and 2 . . .	33	33				
3 and 4 . . .	25	33	33	33		
5 and 6 . . .	20	25	25	33	33	33

3. The thickness for walls for any building where hollow concrete blocks are used shall not be less than is required by law for brick walls.

4. Where the face only is of hollow concrete building-block and the backing is of brick, the facing of hollow concrete blocks must be strongly bonded to the brick, either with headers projecting four inches into the brickwork, every fourth course being a heading course, or with approved ties, no brick backing to be less than eight inches. Where the walls are made entirely of hollow concrete blocks, but where said blocks have not the same width as the wall, every fifth course shall extend through the wall, forming a secure bond. All nails where blocks are used shall be laid up in Portland cement mortar.

5. All hollow concrete building-blocks, before being used in the construction in any buildings in the city of Philadelphia, shall have attained the age of at least three (3) weeks.

6. Wherever girders or joists rest upon walls so that there is a concentrated load on the block of over two (2) tons, the blocks supporting the girder or joists must be made solid. Where such concentrated load shall exceed five (5) tons the blocks for two (2) courses below, and for a distance extending at least eighteen (18) inches each side of said girder, shall be made solid. Where the load on the wall from the girder exceeds five (5) tons, the blocks for three (3) courses underneath it shall be made solid with similar material as in the blocks. Wherever walls are decreased in thickness the top course of the thicker wall to be made solid.

7. Provided always that no wall or any part thereof composed of hollow concrete blocks shall be loaded to an excess of eight (8) tons per superficial foot of the area of such blocks, including the weight of the wall, and no blocks shall be used that have an average crushing strength less than 1000 pounds per square inch of area at the age of twenty-eight days, no deduction to be made in figuring the area for the hollow spaces.

8. All piers and buttresses that support loads in excess of five (5) tons shall be built of solid concrete blocks for such distance below as may be required by the Bureau of Building Inspection. Concrete lintels and sills shall be reinforced by iron or steel rods in a manner satisfactory to the Bureau of Building Inspection, and any lintels spanning over four feet six inches in the clear shall rest on solid concrete blocks.

9. Provided that no hollow concrete building-blocks shall be used in the construction of any building in the city of Philadelphia, unless the maker of such blocks has submitted his product to the full test required by the Bureau of Building Inspection, and placed on file with said Bureau of Building Inspection a certificate from a reliable testing laboratory showing that samples from the lot of blocks to be used have successfully passed the requirements of the Bureau of Building Inspection, and filing a full copy of the test with the bureau.

10. A brand or mark of identification must be impressed in or otherwise permanently attached to each block for purpose of identification.

11. No certificate of approval shall be considered in force for more than four months unless there be filed with the Bureau of Building Inspection, in the city of Philadelphia, at least once every four months following, a certification from some reliable physical testing laboratory, showing that the average of three (3) specimens tested for compression and three (3) specimens tested for transverse strength comply with the requirements of the Bureau of Building Inspection of the city of Philadelphia, said samples to be selected either by a building inspector or by the laboratory from blocks actually going into construction work. Samples must not be furnished by the contractors or builders.

12. The manufacturer and user of any such hollow concrete blocks as are mentioned in this regulation, or either of them,

shall at any time have made such tests of the cements used in making such blocks or such further tests of the completed blocks, or of each of these, at their own expense, and under the supervision of the Bureau of Building Inspection, as the chief of said bureau shall require.

13. The cement used in making said blocks shall be Portland cement, and must be capable of passing the minimum requirements as set forth in the "Standard Specifications for Cement" by the American Society for Testing Materials.

14. Any and all blocks, samples of which, on being tested under the direction of the Bureau of Building Inspection, fail to stand at twenty-eight days the tests required by this regulation, shall be marked condemned by the manufacturer or user and shall be destroyed.

15. No concrete blocks shall be used in the construction of any building within the city of Philadelphia until they shall have been inspected and average samples of the lot tested, approved and accepted by the chief of the Bureau of Building Inspection.

Specifications governing method of testing hollow block:

1. These regulations shall apply to all new materials such as are used in building construction, in the same manner and for the same purposes, as stones, brick, concrete, are now authorized by the building laws, when said new material to be substituted departs from the general shape and dimensions of ordinary building-brick, and more particularly to that form of building material known as hollow concrete block, manufactured from cement and a certain addition of sand, crushed stone or similar material.

2. Before any such material is used in buildings an application for its use and for a test of the same must be filed with the chief of the Bureau of Building Inspection. A description of the material and a brief outline of its manufacture and proportions of the material used must be embodied in the application.

3. The material must be subjected to the following tests: Transverse, compression, absorption, freezing, and fire. Additional tests may be called for when, in the judgment of the chief of the Bureau of Building Inspection, the same may be necessary. All such tests must be made in some laboratory of recognized standing, under the supervision of the engineer

of the Bureau of Building Inspection. The tests will be made at the expense of the applicant.

4. The results of the tests, whether satisfactory or not, must be placed on file in the Bureau of Building Inspection. They shall be open to inspection upon application to the chief of the bureau, but need not necessarily be published.

5. For the purposes of the tests at least twenty (20) samples or test pieces must be provided. Such samples must represent the ordinary commercial product. They may be selected from stock by the chief of the Bureau of Building of Inspection his representative, or may be made in his presence, at his discretion. The samples must be of the regular size and shape used in construction. In cases where the material is made and used in special shapes and forms too large for testing in the ordinary machines, smaller-sized specimens shall be used as may be directed by the chief of the Bureau of Building Inspection, to determine the physical characteristics specified in Section 3.

6. The samples may be tested as soon as desired by the applicant, but in no case later than sixty days after manufacture.

7. The weight per cubic foot of the material must be determined.

8. Tests shall be made in series of at least five, except that in the fire tests a series of two (four samples) are sufficient. Transverse tests shall be made on full-sized samples. Half samples may be used for the crushing, freezing, and fire tests. The remaining samples are kept in reserve, in case unusual flaws or exceptional or abnormal conditions make it necessary to discard certain of the tests. All samples must be marked for identification and comparison.

9. The transveres tests shall be made as follows: The samples shall be placed flatwise on two rounded knife-edge bearings set parallel, seven inches apart. A load is then applied on top, midway between the supports, and transmitted through a similar rounded knife edge until the sample is ruptured. The modulus of rupture shall then be determined by multiplying the total breaking load in pounds by 21 (three times the distance between supports in inches), and then dividing the result thus obtained by twice the product of the width in inches by the square of the depth in inches.

$$R=\frac{3Wl}{2bd^2}.$$

No allowance should be made in figuring the modulus of rupture for the hollow spaces.

10. The compression test shall be made as follows: Samples must be cut from blocks so as to contain a full web section; samples must be carefully measured, then bedded flatwise in plaster of Paris to secure a uniform bearing in the testing machine and crushed. The total breaking load is then divided by the area in compression in square inches. No deduction to be made for hollow spaces; the area will be considered as the product of the width by the length.

11. The absorption tests must be made as follows: The sample is first thoroughly dried to a constant weight. The weight must be carefully recorded. It is then placed in a pan or tray of water, face downward, immersing it to a depth or not more than one-half inch. It is again carefully weighed at the following periods: Thirty minutes, four hours and forty-eight hours, respectively, from the time of immersion, being replaced in the water in each case as soon as the weight is taken. Its compressive strength while still wet is then determined at the end of the forty-eight-hour period in the manner specified in Section 10.

12. The freezlng tests are made as follows: The sample is immersed as described in Section 11, for at least four hours, and then weighed. It is then placed in a freezing mixture or a refrigerator, or otherwise subjected to a temperature of less than 15 degrees Fahrenheit for at least twelve hours. It is then removed and placed in water, where it must remain for at least one hour, the temperature of which is at least 150 degrees Fahrenheit. This operation is repeated ten times, after which the sample is again weighed, while still wet from the last thawing. Its crushing strength should then be determined as called for in Section 10.

13. The fire test must be made as follows: Two samples are placed in a cold furnace in which the temperature is gradually raised to 1700 degrees Fahrenheit. The test piece must be subjected to this temperature for at least thirty minutes. One of the samples is then plunged in cold water (about 50 to 60 degrees Fahrenheit) and the results noted. The second sample is permitted to cool gradually in air and the results noted.

14. The following requirements must be met to secure an acceptance of the materials: The modulus of rupture for con-

crete blocks at twenty-eight days old must average 150, and must not fall below 100 in any case. The ultimate compressive strength at twenty-eight days must average 1000 pounds per square inch, and must not fall below 700 pounds in any case. The percentage of absorption (being the weight of water absorbed divided by the weight of the dry sample) must not average higher than 15 per cent, and must not exceed 20 per cent in any case. The reduction of compressive strength must not be more than $33\frac{1}{3}$ per cent, except that when the lower figure is still above 1000 pounds per square inch the loss in strength may be neglected. The freezing and thawing process must not cause a loss in weight greater than 10 per cent nor a loss in strength of more than $33\frac{1}{3}$ per cent, except that when the lower figure is still above 1000 pounds per square inch the loss in strength may be neglected. The fire test must not cause the material to disintegrate.

15. The approval of any material is given only under the following conditions:

(*a*) A brand mark for identification must be impressed on or otherwise attached to the material.

(*b*) A plant for the production of the material must be in full operation when the official tests are made.

(*c*) The name of the firm or corporation and the responsible officers must be placed on file with the chief of the Bureau of Building Inspection, and changes in the same promptly reported.

(*d*) The chief of the Bureau of Building Inspection may require full tests to be repeated on samples selected from the open market when, in his opinion, there is any doubt as to whether the product is up to the standard of these regulations, and the manufacturer must submit to the Bureau of Building Inspection once in at least every four months a certificate of tests showing that the average resistance of three specimens to cross-breaking and crushing are not below the requirements of these regulations. Such tests must be made by some laboratory of recognized standing on samples selected by a building inspector or the laboratory, from material actually going into construction, and not on ones furnished by the manufacturer.

(*e*) In case the results of tests made under these conditions should show that the standard of these regulations is not maintained, the approval of this bureau to the manufacturer of said blocks will at once be suspended or revoked.

REGULATION OF CONCRETE BLOCKS IN NEWARK, N. J.

The building regulations regarding concrete construction recently adopted by the city of Newark, N. J., are much shorter and more specific, and therefore do not cover all the conditions which may arise, as well as the Philadelphia regulations. Where detailed tests are difficult to secure there may be some excuse for this class of rules, but on the one hand they will work hardships in many cases, and on the other it is not probable that they will permit positively bad construction if they are conscientiously enforced.

Cement Built in Forms.—Cement built in forms shall consist of a standard Portland cement, one part cement, two parts of sharp grit sand, free from loam or dirt, four parts broken stone no greater than one and a half inch in diameter, and no walls or building of this construction shall be higher than twenty (20) feet; above this height must be steel-concrete construction. This construction is for foundation to grade. No ashes will be allowed.

Concrete Blocks or Artificial Stone.—Cement building-blocks shall be constructed of a standard Portland cement mixed with sharp grit sand free from loam or dirt, crushed stone, slag or gravel in proportions of one to four—one part cement, one and a half part of sand to two and a half parts of crushed stone, to pass through a three-fourths-inch screen.

Blocks shall not be larger than thirty-six inches long and ten inches in height, and not less than eight inches nor greater than sixteen inches wide. Blocks may have one or more hollow spaces, provided that no more than one-third of each block is hollow.

Blocks shall be at least thirty days old before being used in any building wall, and stand a tensile test of 150 pounds to the square inch and 1500 pounds compression test.

Strength and Tests of Building Blocks.—Recently W. M. Scott of the Hayden Automatic Block Machine Co., of Columbus, Ohio, had a number of tests of blocks made, the result of which is given in the following table. The blocks were tested at various ages, as shown.

The blocks were made of lake sand. Plain block with a mixture of 2 parts sand and 1 part cement for the face of block and ½ inch thick on face.

The balance of the block was a mixture of 4 parts sand and 1 part cement. The three months' old blocks were tested by the Ohio State University, Columbus, Ohio, 1900 pounds to the square inch.

The six months' old blocks were the same sand and mixture as the three months' old blocks and made on the same machine and tested by the Watertown Arsenal, Watertown, Mass. All blocks tested were made on the Hayden machine for the manufacturers, Watertown test, 2930 pounds to the square inch.

Actual Size, which Allows for $\frac{1}{4}''$ of Mortar. Inches.	No. of Inches.	Air Space. Inches.	No. of Inches.	Amount of Material. Inches.	Strength, at		
					3 Mos. Pounds.	3 Mos. Tons.	6 Mos. Tons.
$8\times8\frac{3}{4}\times31\frac{3}{4}$	2222	$2-3\times10$	587	1633	368,600	184	284
$9\times8\frac{3}{4}\times31\frac{3}{4}$	2500	$2-4\times10$	762	1738	389,500	$194\frac{1}{4}$	300
$10\times8\frac{3}{4}\times31\frac{3}{4}$	2778	$2-4\times10$	763	2015	450,300	225	347
$12\times8\frac{3}{4}\times31\frac{3}{4}$	3333	$2-4\times10$	764	2569	568,100	284	438
$12\times8\frac{3}{4}\times31\frac{3}{4}$	3333	$2-6\times10$	1114	2219	492,100	246	379
$16\times8\frac{3}{4}\times31\frac{3}{4}$	4445	$2-9\times\ 9$	1455	2990	657,400	$328\frac{1}{2}$	565

In a paper read before the convention of N. A. C. U. at Chicago, January 1907, R. D. Kneal, Instructor in Civil Engineering, Purdue Univeristy, gave the result of tests on a number of blocks as follows:

This paper is a description of the tests of some thirty plain concrete building blocks which were about one year old. These blocks were of the usual block type, $16\times8\times6$ inches, with two 4×5-inch inside openings. All were made of the same materials and treated as nearly alike in manufacture as possible. The materials used were gravel 100 per cent fine on a sieve of $\frac{1}{2}$-inch mesh, and Lehigh Portland cement. The proportions were 1 of cement to 5 of gravel. Each block was faced with 1:2 mortar, using the same cement as in the body of the block, and using an ungraded, clean river sand. The faces were so well bonded to the block that in no case did failure occur between facing and block. The faces were approximately $\frac{1}{2}$ inch thick, and were not considered in figuring the cross-section used in compression tests. After initial curing the blocks were stored outdoors without covering. They were selected at random for the test from large piles exhibited for sale.

The blocks were tested in the laboratory for testing materials at Purdue University. The results of the tests are as follows:

Six blocks were broken in flexure. Two 1-inch wrought-iron rollers were placed 14 inches apart on the platform of a Riehle 200,000-pound vertical testing-machine. On these rollers the block was placed, with the facing vertical. A third roller, 1 inch in diameter, was placed parallel to the others, on the centre line of the block, and the compression head brought down on this roller. The results given below show fair uniformity:

Flexure. No.	Span.	Load at Failure.	Modulus of Rupture. (lbs. per sq. in.)
1	14 inches	6,040 lbs.	300
2	14 "	5,270 "	260
3	14 "	4,900 "	242
4	14 "	3,900 "	192
5	14 "	4,300 "	212
6	14 "	4,880 "	240
	Average,	4,485 lbs.	241

Twenty-four blocks were tested in compression—six in columns one block high, two columns two blocks high, two columns three blocks high, and two columns four blocks high. To give an even bearing on the machine, the columns were bedded in plaster, and to give an even bearing on each other in the column one series of blocks was cemented into columns with plaster, the other series with neat Portland cement. This difference of bedding material, however, gave no appreciable variation in results. All columns failed in similar vertical planes through the partition walls. The results of the compression test are given in the table on page 286, the 200,000-pound Riehle vertical testing-machine being used.

Weight.—The average weight per block was 55 pounds. The average weight per cubic foot of material was 147 pounds.

Absorption.—Half blocks, after drying two days in the heating oven, were immersed in water and absorbed in 6½ per cent by weight after four hours' immersion. After four days' immersion this per cent of absorption increased only ½ per cent. On immersing the face only, it absorbed 2.3 per cent of the weight immersed in four hours.

Summary.—The results of the test then show that the modulus of rupture is 241 pounds per square inch, which is 85 per cent of that determined by Fuller for 1:3:5 concrete beams.

LOADS IN 1,000 POUNDS.

Test.	Columns Tested.	Blocks in Columns.	First Crack.					
			Total.			Pounds per Sq. In.		
			Max.	Min.	Avg.	Max.	Min.	Avg.
1	5	1	195	106	146	2.19	1.15	1.63
2	2	2	145	106	126	1.63	1.22	1.43
3	2	3	145	100	123	1.63	1.15	1.69
4	2	4	146	119	133	1.63	1.36	1.49
			Maximum.					
1	5	1	195	107	152	2.19	1.17	1.67
2	2	2	145	115	130	1.63	1.32	1.47
3	2	3	163	115	139	1.63	1.20	1.41
4	2	4	146	119	132	1.63	1.36	1.49

The strength per square inch in compression averages 1500 pounds, or about 60 per cent of the strength of solid cubes and cylinders of 1:3:5 concrete as given by various authors. This compressive strength shows little variation for columns of four blocks high.

Results throughout the test checked with fair uniformity.

Tests made under the specifications of the city of Philadelphia on concrete blocks in the market have developed about the following results:

Modulus of rupture, 150 to 175 lbs.

Compressive strength, 1200 to 1600 lbs. per square inch.

Absorption, 5 per cent.

The compressive strength is reduced little, if any, by the water absorbed.

Freezing tests show little loss.

The average compressive strength after freezing is in the vicinity of 1000 lbs. per square inch.

The blocks passed the fire tests well.

Cost of Cement and Plaster Work. — No rule or set schedule of prices can be prepared that will apply to all concrete work, as all concrete work and conditions under which it is done are not alike; hence only approximate costs can be given. The approximate prices given below are based on the work being done by skilled mechanics at the following wages: Cement finishers, 50

cents per hour; carpenters, 50 cents per hour; laborers, 25 cents per hour.

The unit prices on concrete includes the forms.

Sidewalks and floors, 4″ base, 1″ top coat, will cost from 12 to 18 cents per square foot.

Curbs, 6″×2′ 6″, will cost from 45 to 60 cents per linear foot.

Pavements, 6″ base, 1″ top, cut into blocks 6″×6″, will cost about 30 cents per square foot.

Concrete foundations, walls, etc., with no reinforcement, will cost from $5.00 to $9.00 per cubic yard, according to the size and shape of the work.

Reinforced retaining walls will cost from $8.00 to $13.00 per cubic yard.

Reinforced concrete in buildings, floors, columns, etc., will cost from $20.00 to $30.00 per cubic yard. A price of $1.00 per cubic foot is often used to approximate the cost of reinforced concrete in buildings and like work.

Beam and slab floors will cost from 40 to 50 cents per square foot, according to the thickness and reinforcement.

Slab floors and beam covering in steel skeleton construction will cost from 25 to 40 cents per square foot of floor surface.

For estimating approximately the cost of reinforced concrete, Ernest McCullough in "Reinforced Concrete, a Manual of Practice," gives the following rule:

"Get the exact costs of sand, stone, and cement delivered on the job and reduce the costs to the cost per cubic yard of concrete. To this add $5.00 per cubic yard for steel. This will be one-half—3/6 the cost per cubic yard of concrete in place. The labor on concrete and steel will be 1/6, and the material and labor on forms will be 2/6. For average buildings containing about 2000 cubic yards of concrete this will be about true. Add 2 per cent to cost for each 100 yards less than 2000. Complicated work will increase the cost greatly. To this price must be added cost or rent of plant, and the profit of the contractor."

Cost of Concrete Forms.—The cost of forms, like that of concrete, varies according to the nature of the work, and no set price or rule can be given for obtaining the cost.

Form work in general will cost from $15.00 to $25.00 per thousand feet B. M in addition to the cost of the lumber. If the lumber is used the second time, the price of labor will be increased about $5.00 per thousand feet B.M.

The forms for buildings, floors, columns, beams, and like construction will cost from $6.00 to $8.00 per cubic yard of concrete.

Forms for arches, bridges, and heavy work will cost from $2.00 to $3.00 per cubic yard of concrete.

To take down, clean and draw the nails from form lumber will cost from $2.50 to $3.50 per thousand feet B. M.

Cost of Cement Blocks.—With labor at 30 cents per hour, cement at $2.00 per barrel and sand and gravel at $1.50 per yard, the cost to manufacture cement building blocks, excluding the depreciation of plant and profit, will be about as follows:

8″× 8″×16″	blocks will cost about	9	cents each;
8″× 8″×24″ or 8″×12″×16″	" " " "	14	" "
8″×12″×24″	" " " "	23	" "

With mason labor at 50 cents per hour and helper at 25 cents per hour the cost of laying cement blocks will be about 6 cents per square foot of wall surface.

Cost of Plastering.—Including lath. 3-coat work, plaster Paris finish:

Lime plaster on masonry	25–30	cents per sq. yd.
" " " wood lath	30–35	" " "
" " " metal lath	55-65	" " "
Patent or hard plaster on masonry	35–40	" " "
" " " " " wood lath	40–45	" " "
" " " " " metal "	65–80	" " "
Cement plaster on masonry	60–75	" " "
" " " metal lath	80–90	" " ".

For Keen's Cement finish add to the above price 7 cents per square yard.

PART VI.

LATHING AND PLASTERING, LATHING AND FURRING, MATERIALS FOR MAKING PLASTER, APPLYING PLASTER, USE OF HARD OR PATENT PLASTER, VARIOUS WORK DONE BY PLASTERERS, ESTIMATING PLASTERING, TABLES FOR ESTIMATING.

Wood Lathing.—Wooden laths are strips of wood sawed $\frac{3}{8}$ inch thick, 1 inch, $1\frac{1}{4}$ inch, $1\frac{3}{8}$ inches, and $1\frac{1}{2}$ inches wide, and usually 4 feet long. No. 1 laths are of white pine, spruce, or cedar, and free from large knots, bark, or other defects, and are of uniform dimensions. No. 2 laths are usually made from hemlock, hard pine, or culls from the stock for No. 1 laths, and are not of uniform dimensions.

In putting on the laths they should have a nail to each bearing, and very often specifications for the work will call for two nails at each end. When putting on the laths the lather should see that all studs and joist are straight and in line. If any are not straight or out of line, he should call the attention of the carpenter to it and have the joists or studs straightened before putting on the laths.

The laths for ordinary lime-mortar should be spaced about $\frac{3}{8}$ inch apart, and for the patent or hard plasters should be spaced about $\frac{1}{4}$ inch apart.

The perpendicular joints in the laths should be broken about every sixth course, or lath.

No lath should be set vertical to fill out corners or any other place.

When the laths cross a bearing over 2 inches in width a lath or strip should be put under the laths, so there will be a space back of the laths for the plaster to key.

Laths over doors or other openings should have as few vertical joints as possible, so as to prevent vertical cracks in the plaster. If possible the laths should extend across the opening.

Data on Wood Laths.—Laths are usually packed in bundles of 100 laths each.

1000 laths $1\frac{1}{4}$ inches wide, spaced $\frac{1}{4}$ inch apart, will cover about 480 square feet.

1000 laths $1\frac{3}{8}$ inches wide, spaced $\frac{1}{4}$ inch apart, will cover about 530 square feet.

1000 laths $1\frac{1}{2}$ inches wide, spaced $\frac{1}{4}$ inch apart, will cover about 570 square feet.

1000 laths $1\frac{1}{4}$ inches wide, spaced $\frac{3}{8}$ inch apart, will cover about 530 square feet.

1000 laths $1\frac{3}{8}$ inches wide, spaced $\frac{3}{8}$ inch apart, will cover about 570 square feet.

1000 laths $1\frac{1}{2}$ inches wide, spaced $\frac{3}{8}$ inch apart, will cover about 620 square feet.

1000 laths dry weighs about 500 lbs.

1000 laths green or wet weighs about 950 lbs.

A good lather will put on from 1200 to 1700 laths in 8 hours.

Metal Lathing.—There are a number of different metal or wire laths now on the market. The metal lath being an expanded or perforated strip of sheet metal, while the wire lath is made of wire woven together. The wire lath is usually stiffened with round rods or V-shaped strips of metal woven in the mesh of the lath every 6 or 7 inches.

The wire lath is sold in rolls of various widths from 16 inches to 49 inches, and is made of No. 18, 19, 20, 21, and 22 gauge wire.

Wire lath is usually painted or galvanized to prevent rusting. If marked "Galvanized" it means that the lath has been galvanized after weaving, but if marked "Galvanized Material," it indicates the lath is made from wire that was galvanized before weaving. The lath that has been galvanized after weaving is stiffer than the other, as the galvanizing solders the wire rigid at each intersection.

Expanded Metal Lathing.—Expanded metal lath is made by cutting and expanding strips of sheet metal. The strips

being expanded to several times their original width. Metal lath is packed in bundles of usually 20 sheets, each sheet containing about 1 square yard.

Expanded metal lath should be put on so the slope of the ribs of the lath is downward toward to studding. Fig. 170 shows the right and the wrong way of putting on expanded metal lath.

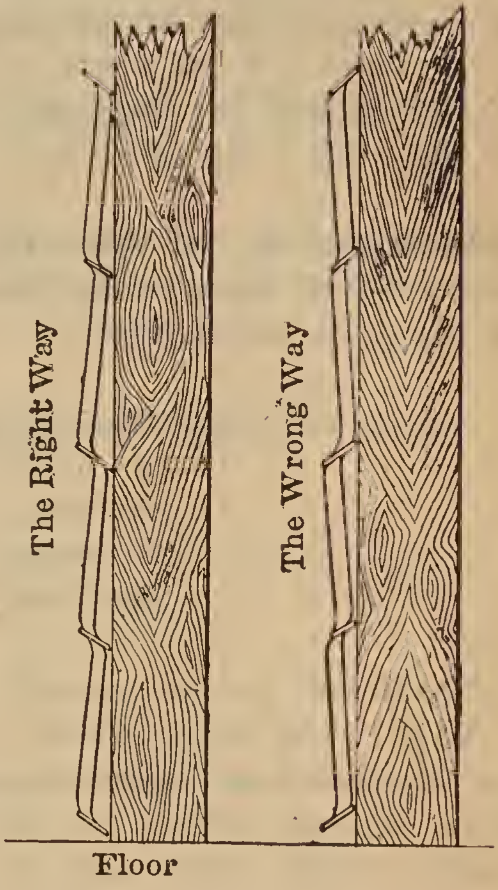

FIG. 170.—Right and Wrong Way of Applying Metal Lath.

Metal lath should always be coated to prevent rusting. It is usually so coated at the factory before shipping. A good coating for metal lath is made of coal-tar cut with benzine. To coat the lath fill a trough with the liquid and dip the lath in bundles, then set away to dry. In all angles where wood or terra-cotta partitions join the main wall of the building there should be a strip of the metal lath bent in the angle and extending out on each side about 6 inches and securely fastened; this will prevent any cracks in the angles after the plastering is done.

CORNER BEADS.—Metal corner beads should be used on all external angles, and care must be taken in setting them to get them straight and fastened solid.

Data on Wire and Metal Lath.—Wire lath is usually put up in rolls containing a length of about 50 yards.

1 pound of $\frac{7}{8}$-inch staples will fasten on about 10 yards of wire or metal lath.

1 keg of $\frac{7}{8}$-inch staples will fasten on about 1000 yards of wire or metal lath.

A sheet of metal lath usually contains 1 square yard with an allowance for lap.

Wire or metal lath should be fastened every 4 inches on all bearings.

All wire, staples, etc., used to fasten wire or metal lath, should be galvanized to prevent rusting.

Studding, joist, etc., for wire and metal lath should never be spaced more than 16 inches on centres, and 12 inches will make a better job.

To make a minimum carload of 30,000 lbs. of metal lath, it requires, for each of the gauges, about the following:

10,700 yards of No. 28 gauge.	9,000 yards of No. 26 gauge.
9,700 " " No. 27 "	6,700 " " No. 24 "

Weights, etc., of Wire Lath.—Number.—The number of the wire lath indicates the size of the wire; the numbers refer to the gauge as follows:

No. 18 = 0.047 inch in diameter
" 19 = 0.041 " " "
" 20 = 0.035 " " "
" 21 = 0.032 " " "
" 22 = 0.028 " " "

No. 20 lath is more generally used than any other size.

Mesh.—The term "mesh" in connection with wire lath is the distance from centre to centre of the wires and not the space between them. The mesh is usually designated by the number to the inch thus:

2×2 mesh means wires $\frac{1}{2}$ inch centre to centre.
$2\frac{1}{2} \times 2\frac{1}{2}$ " " " $\frac{2}{5}$ " " " "
3×3 " " " $\frac{1}{3}$ " " "
$2\frac{1}{2} \times 4$ " " " $\frac{2}{5}$ " " " " , measuring along the warp, and $\frac{1}{4}$ inch centre to centre measuring along the filling.

The $2\frac{1}{2} \times 2\frac{1}{2}$ (meshes to the inch) lath is adapted to all plasters containing the usual proportion of hair or fibre. It is the standard mesh.

The regular close-warp, $2\frac{1}{2} \times 4$ mesh, is adapted to the hard plasters, such as King's Windsor cement, Adamant, and the like. Painted or galvanized lath should generally be used in connection with special plaster compounds.

The 3×3 mesh is also adapted to the hard plasters and is a trifle less expensive than the regular close warp.

The hard plasters can also be applied to the $2\frac{1}{2} \times 2\frac{1}{2}$ mesh wire lath.

Width.—Wire lath can be furnished to order in any required width up to ten feet. In widths less than 18 inches there is a small charge for "stripping." Before ordering, it is very important to ascertain the proper width, especially in stiffened lath, as it is desirable to have the edges of the lath join at supports when applied to woodwork, and lap at supports when laced to iron furring. When the lath is not of the proper width the results will not be so good and there is liable to be a waste of material.

The standard width of plain and of V-rib stiffened lath is 36 inches. When beams or studs are spaced 16 inches centre to centre the lath should be 32 or 49 inches wide.

Weight of Youngstown Corrugated Expanded Metal Lath.

No. 28.	Corrugated	expanded	lath,	$2\frac{1}{5}$	lbs.	per	square	yard.
No. 27.	"	"	"	$3\frac{1}{10}$	"	"	"	"
No. 26.	"	"	"	$3\frac{2}{5}$	"	"	"	"
No. 24.	"	"	"	$4\frac{1}{2}$	"	"	"	"

Weight of Herringbone Expanded Steel Lath.

GRADE A AND AA.

28 gauge	3	lbs.	to	one	square	yard
27 "	$3\frac{1}{3}$	"	"	"	"	"
26 "	$3\frac{2}{3}$	"	"	"	"	"

GRADE B AND BB.

28 gauge	2	lbs.	per	square	yard
27 "	$2\frac{1}{4}$	"	"	"	"
26 "	$2\frac{1}{2}$	"	"	"	"
24 "	$3\frac{3}{8}$	"	"	"	"

Weight of Berger's Key-lock Expanded Metal Lath.

No. 27 gauge	$3\frac{1}{10}$	lbs.	per	square	yard
" 26 "	3_{5}	"	"	"	"
" 24 "	$4\frac{1}{2}$	"	"	"	"

Weight of "Acme" Sheet-metal Lath.

(Made in sheets 15×96 inches.)

Grade A, 30 gauge	$3\frac{8}{10}$ lbs. per square yard
" B, 29 "	$4\frac{6}{10}$ " " " "
" C, 27 "	4 " " " "

Weight, etc., of Expanded Metal Lath.

Grade.	Gauge.	Size of Sheet. Inches.	Sheets in Bundle.	Yards in Bundle.	Weight per Yard. Pounds.
A. Government standard . . .	24	18×96	9	12	$5\frac{1}{3}$
C. Standard mesh	27	16×96	9	$10\frac{2}{3}$	$3\frac{3}{10}$
D. Diamond mesh {narrow strand}	24	21×96	9	14	$3\frac{3}{15}$
D. Diamond mesh {broad strand}	24	24×96	9	16	$3\frac{1}{2}$

Weight, etc., of Sykes Metal Lath.

Expanded cup lath,	28 gauge,	weighs	3	lbs. per sq. yd.
" " "	27 "	"	$3\frac{1}{4}$ to $3\frac{1}{2}$	" " " "
" " "	26 "	"	$3\frac{3}{4}$ to 4	" " " "
" " "	24 "	"	$4\frac{1}{2}$ to 5	" " " "

Sykes Trough Lath.

28 gauge	weighs	$5\frac{1}{4}$ to $5\frac{1}{2}$	lbs. per sq. yd.
27 "	"	$5\frac{3}{4}$ to 6	" " " "
26 "	"	$6\frac{1}{2}$ to 7	" " " "
24 "	"	$7\frac{1}{2}$ to 8	" " " "

Metal Furring.—Metal furring is generally used for forming the shape of pilasters, columns, false beams, etc. The shape is usually formed by brackets made of flat or small channel irons bent to the desired shape, and fastened in place with bolts, clamps, etc. To these brackets or forms are fastened longitudinal ribs of round or flat iron, and over this frame is bent and fastened the wire or metal lath, the lath being wired fast to the iron frame.

All the iron brackets, ribs, etc., used for furring should have a heavy coat of paint to keep the iron from rusting.

Figs. 171, 172, and 173 show method of putting up metal furring. The brackets and ribs of all furring should be fas-

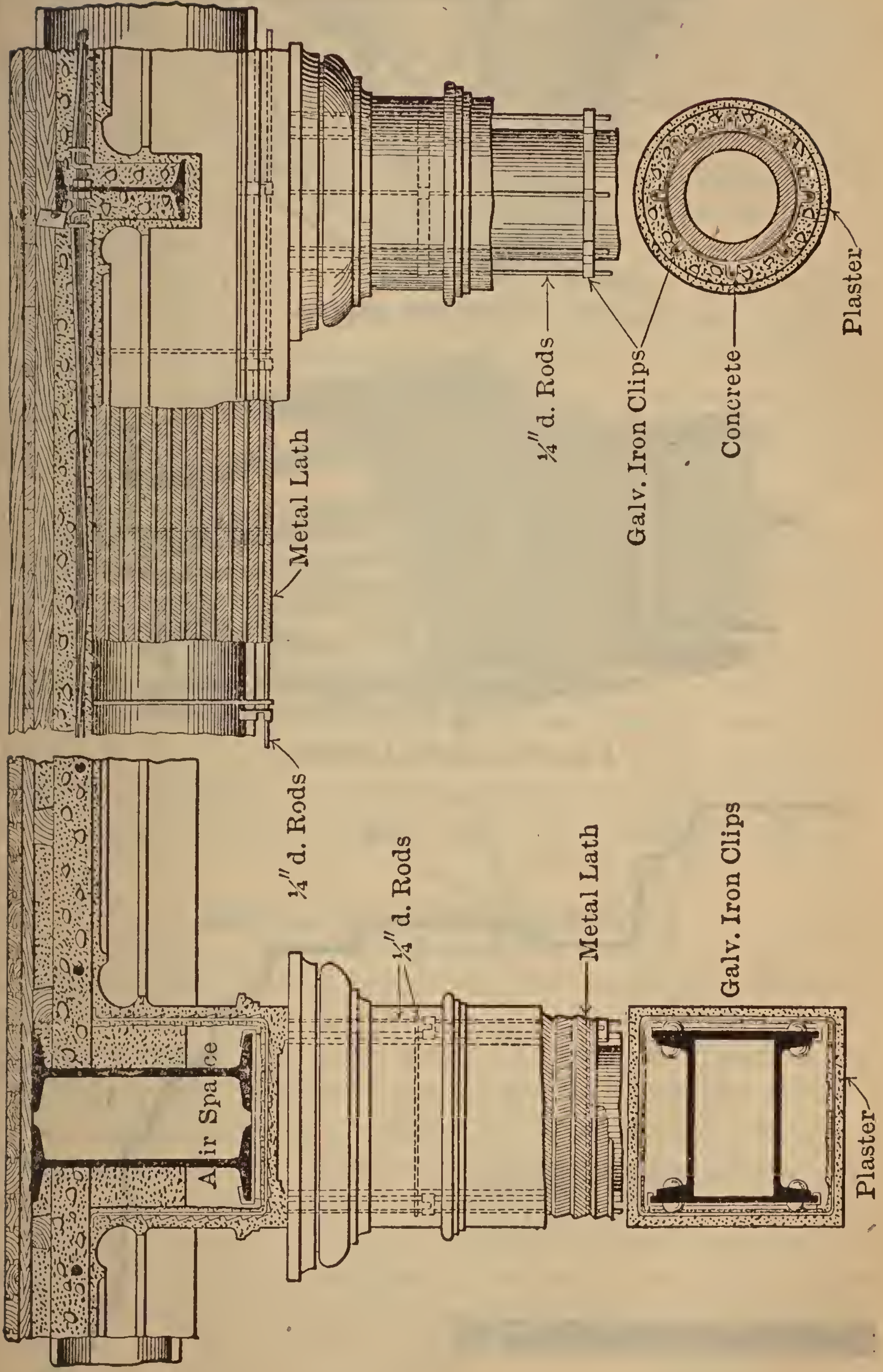

Fig. 171.—Columns and Girder Furring.

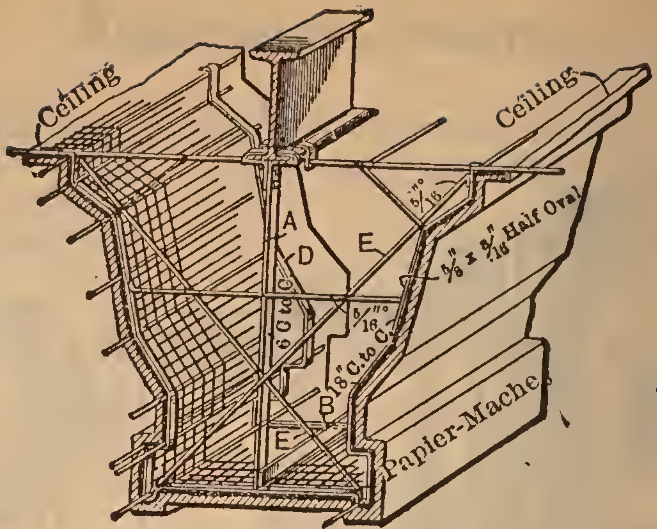

Fig. 172.—Girder Furring.

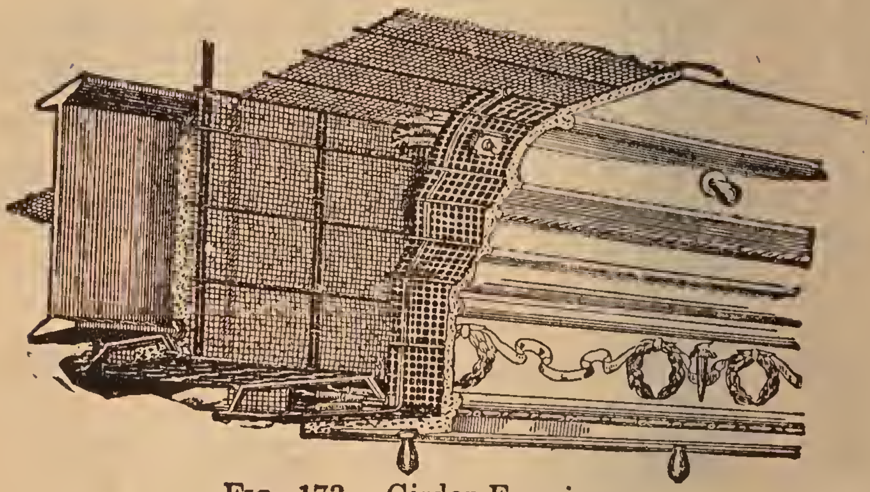

Fig. 173.—Girder Framing.

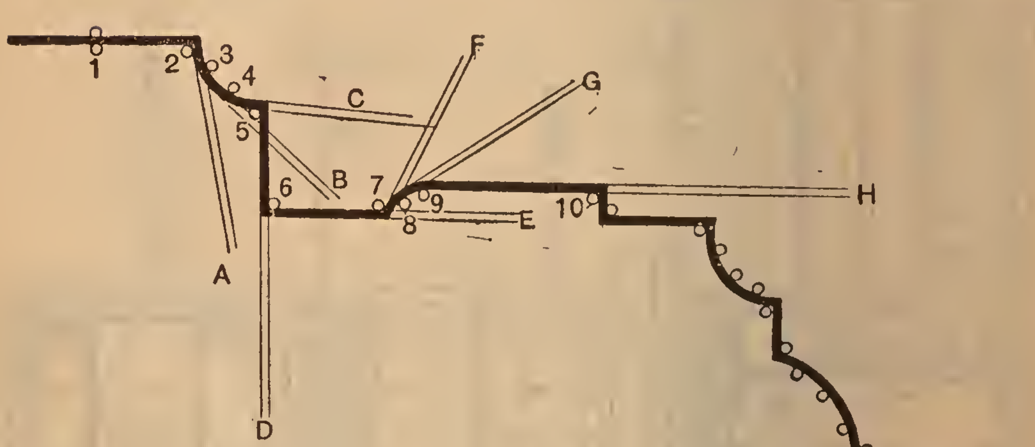

Fig. 174.—Bending Furring Bracket.

Fig. 175.—Tool for Bending Bracket.

tened as firm and rigid as possible to prevent any cracking in the finished plastering and stucco work.

Bending of Brackets for Furring.—A good method of bending brackets for furring is illustrated by Fig. 174. On a bench or table mark out the shape of the bracket as shown, then at each angle and around the curves bore holes in the bench or table top in which to insert iron pins, as the bracket is bent.

When many brackets of the same shape are to be bent or formed these holes should be made large enough in which to drive short pieces of about $\frac{1}{4}$-inch gas-pipe. These pieces of pipe should be driven down flush with the bench top, thus forming a casing to each hole and will prevent the holes from wearing large or irregular by much use. A number of pins should now be cut to insert in these pipes as the bracket is bent, and wooden plugs can be driven in the pipes to a certain depth to prevent the pins from dropping through the pipe.

To bend the bracket, place a strip of flat or channel iron between the two pins at 1, Fig. 174, and with a monkey-wrench or a tool, as shown by Fig. 175, bend the iron around the pin at 2, to the position indicated by the dotted lines *A*. Now insert pin 3 and bend into position shown at *B*, insert pin 4 and bend to position *C*; insert pin 5 and bend to position *D*. Continue thus until all angles and turns are made and the bracket completed. By this method all the brackets will be alike.

A "break" for bending metal lath is described on page 150.

Materials for Making Plaster.

Lime.—Lime for making mortar for plastering should be the very best quality and free from all dirt. It should slake readily so there will be no unslaked particles of lime in the mortar to slake after it is put on the wall. If this happens the small pieces of lime swelling and slaking will cause small pieces of the plaster to fall off, leaving "pits" or holes. The lime should be slaked at least a week before being put on the wall.

All lime used for plastering should be freshly burned and should not have been exposed to the air to cause it to "air slack" and render it unfit for use.

When wet with water it should slake readily into a smooth, fine paste or putty. The lime should slake by simply immersing it in the water, although stirring it will hasten it somewhat.

For a more complete description of lime, see page 80.

Hydrated Lime.—Hydrated lime is lime that has been partially slaked by means of steam and reduced to a powder without giving it moisture enough to form a paste.

Hydrated lime is much used for the white coat of plaster, and gives a superior finish. A finish of hydrated lime is not so liable to have "pits," "hair cracks," etc., as the lime slaked in the ordinary way. Hydrated lime is usually brought to the work in sacks and should be wet or mixed the night before using, then as used it can be "gauged" up with plaster of Paris ready for use.

Sand.—The sand should be sharp and angular, free from any dirt or oil or anything to stain the plaster. When sea sand is used it must be thoroughly washed with fresh water so as to remove all salt.

For further information on sand see page 79.

Hair and Fibre.—These are used in the mortar to form a bond and bind the sheet of mortar together. Cattle hair is generally used, but of late years jute and several fibre products have been used satisfactorily to a great extent.

Recent tests made to show the relative strength of manila hemp, sisal hemp, jute, and goats' hair show manila fibre is the strongest binder for plaster, the others ranking as follows: sisal fibre, jute fibre, and goats' hair.

Plaster of Paris.—Plaster of Paris is prepared by grinding and heating natural gypsum in a furnace so as to drive off its water of crystallization. Plaster of Paris owes its value to the property it possesses of absorbing water and passing into the water-soaked condition, in doing which it sets into a hard mass. This setting takes place quickly, but sufficient time elapses between mixing it with water and setting to permit it to be run into moulds or for coating surfaces, and to gauge the skim or finish-coat and for running cornices, centre-pieces, and other ornamental work. Plaster of Paris should be kept in a dry place, as it readily absorbs moisture.

Patent or Hard Plasters.—There are a number of hard or patent plasters on the market and sold under various names, as Adamant, King's Windsor, Rock Wall, Granite, Elastic Pulp, Ideal, Elyria Wood, Kallolite, Imperial Wall, etc.

The composition of the various plasters is pretty much the same, the hardness being based on the plaster of Paris or gypsum used in their manufacture. These plasters give good satisfaction and make a hard durable job of plastering. For

quick work or for use in cold weather they are preferable to lime plaster, as they will set and harden much quicker.

The manufacturers of patent or hard plasters usually prepare a white finish for finishing their wall plaster. This is usually a mixture of hydrated lime and plaster of Paris, with a retarder to hold back the setting of the plaster of Paris. Usually these white finishes set up very quickly, and for good work can be improved by adding about 10 per cent of lime putty; this holds back the setting and a better finish can be given.

Lafarge Cement.—Lafarge cement is much used for outside stucco-work. It should be used as follows:

First coat: 1 part cement, 3 parts sand, 25 per cent lime paste, and sufficient hair.

Second coat: 1 part cement, 2 parts sand, 10 per cent lime paste. 1 barrel of cement and 3 of sand will cover about 34 square yards $\frac{3}{8}$ inch thick.

Keene's Cement.—This cement, or plaster, is made by recalcining plaster of Paris after soaking it in a solution of alum; it is used for wainscot, base, caps, etc., and also for hard finish.

The first coat is composed of 1 part cement, 1 part lime paste, and 3 parts sand.

The second coat of 1 part cement, 1 part lime paste, and 4 parts sand.

Patent Soapstone Finish.—This is a finish coat manufactured by the American Soapstone Finish Co., Chester Depot, Vt. It is a soft blue in color, and makes a very good finish. It is also put up in various colors. When colored it is shipped in kegs wet ready for use.

Applying Plaster.—When doing a job of plastering the plasterer should examine the grounds as he goes along with his work to see that they are solid and straight. The plasterer is supposed to work to the grounds, and if the grounds have been put in place by a careless carpenter and are crooked, then the plastering will be crooked.

All grounds should be examined just before putting on the first coat of plastering, and if any are found not straight the carpenter should be called to go over and straighten them.

All stone, brick, and terra-cotta walls should be thoroughly drenched with water before applying the first coat of mortar,

and if a stud wall with dry wooden lath, it also should be thoroughly wet.

The plasterer should ascertain from the carpenter if the grounds have been set the exact size of the wood jambs, etc., and if no allowance has been made for the white coat, he should work the brown coat down so the skim or white coat will come flush with the grounds. It is better for the carpenter to set his grounds about $\frac{1}{8}$ inch narrower than the finished work, as this will then allow for the thickness of the skim coat.

When plastering all the openings of the building should be closed to prevent wind and draughts from drying out the plaster too quick. This is especially urgent when the skim coat is being put on; if there is much wind it will dry too fast and cause small hair cracks.

If from any cause there is any part of a wall that cannot be finished when the skim coat is applied, it is best to leave this wall to be finished at a future time and stop the other work at the corner or angle; work finished afterwards to an angle or corner will not show the joint between the two finishes.

When plastering below the base grounds the plasterer should take especial care to get the plaster straight and plumb, so the carpenter will have no trouble when he comes to put down the base; care should also be taken at all angles to get them straight and square.

In putting on the skim coat sufficient troweling should be given to bring it to a smooth glossy surface. By looking along the finished walls where the light strikes them one can tell if they have a good finish; there should be no trowel- or brush-marks on the finished surface.

Lime Plaster.—Lime and sand plaster should be made up at least a week before it will be required for use. Ordinarily the hair is mixed with the mortar when it is made up, but on first-class work it should be added when the mortar is mixed for use.

When the hair is added to the mortar when the lime is first slaked there is danger of the hot lime burning the hair and causing it to rot.

The proportions of lime and sand to use for making lime mortar for plastering will vary, according to the quality of the lime used, the average mixtures being about as follows:

Lime Plaster.

Scratch Coat.—1 bbl. lime, 7 bbl. sand, 2 pounds hair or fibre.

Brown Coat.—1 bbl. lime, 8 bbl. sand, 1 pound hair or fibre.

Lime-cement Plaster.

Scratch Coat.—1 bbl. lime, 12 bbl. sand, 1½ pounds hair or fibre.

Gauging.—Add 1 part Portland cement to 4 parts of the above mortar.

Brown Coat.—1 bbl. lime, 14 bbl. sand.

Gauging.—Add 1 part Portland cement to 4 parts of the above mortar.

Lime-cement Plaster for Exterior Work.

Scratch Coat.—1 bbl. lime, 12 bbl. sand, 2 pounds hair or fibre.

Gauging.—Add 1 part Portland cement to 3 parts of above mortar.

Finishing Coat.—1 part Portland cement, 2½ parts sharp sand or crushed granite.

Patent or Hard Plasters.—Patent or hard plasters are a product of gypsum rock, ground to a suitable fineness, calcined for elimination of a certain percentage of the combined moisture and the addition of some property to interfere with the rapid crystallization, or to retard the setting of the plaster to give time for the plasterers to trowel, and work the plaster to the desired finish.

These plasters are usually prepared for use by the addition of clean water only, having the proper proportion of cleaned and dried sand added and mixed by machine.

Some plasters have asbestos fibre, fire-clay, or hydrated lime added, and which are claims for improvement by the various manufacturers.

Patent or hard plaster for use on wood or metal lath must have a fibre mixed with it to act as a binder to hold the wet plaster in the crevices of the lath until the plaster has set.

Patent plasters attain their natural strength in from 24 to 48 hours after water has been added.

Patent plasters do not dry, they set first; hence they cannot be retempered and worked over.

Do not let patent plaster dry out quickly by heat or wind; the moisture should not be evaporated. The plaster sets, and this moisture is required to cause crystallization.

Lime-water or alum-water makes patent plaster set more quickly.

Citric acid dissolved in water, or glue-water, will retard the setting of patent plaster.

GROUNDS.—Grounds for patent plaster should be $\frac{3}{4}$ inch for wood lath, $\frac{1}{2}$ or $\frac{5}{8}$ inch for brick or tile, $\frac{3}{8}$ inch over face of wire or metal lath.

Directions for Applying Patent or Hard-wall Plasters.—As nearly all patent or hard-wall plasters are of about the same composition the following directions for their use are given:

GENERAL DIRECTIONS FOR MIXING AND APPLYING PATENT OR HARD PLASTERS.—*Base Coats.*—Mix in water-tight box about $3\frac{1}{2}$ by 7 feet, raised about 4 inches at one end. If an old box is used, be sure that it is free from dirt and lumps of old cement. Put the dry plaster in raised end and water in lower end and hoe former into water, mixing thoroughly as you go along. Mix thin at first, as this insures free chemical action and prevents the material from getting lumpy. Stiffen with dry plaster and work to the proper consistency. Do not mix up more material than can be handily used in about one hour. Clean box after each gauging and do not mix one batch with another. In applying on wood lath, lay on lightly, filling up grounds as you go along. Sprinkle lightly with water to prevent tearing under darby. Straighten with rod and darby, and before leaving finally, use the float, knocking off bumps and filling up cat-faces, but *do not water float*, as you are liable to kill face of work.

Dry wood lath should be wet before applying mortar, as otherwise they are liable to buckle.

On brick or tile, it is well to set work liberally before plastering. For repair work, soak *old lath* with water before plastering.

Finish Coats.—In gauging finish coats, it is essential that mixing box and water should be clean. Use about a bucket and a half of water to each sack of finish, putting the dry plaster in raised end of box and hoeing it into water and mixing same as before. Work the mixture thoroughly until there are no bubbles or lumps left in it, and see that tools are kept per-

fectly clean. Finish coats should be gauged thin, and can be carried in buckets instead of the hod.

In applying trowel finishes, go over the wall the first time and grind in just as thin as possible, thoroughly covering the ground. Three or four men can in this way go over a large ceiling before coming back to cover up. It is essential that this first coat should have time to draw, and it is very easy to find out when this has taken place, as you will find it full of thousands of little holes, showing that the material has gone into the base coat and expelled the air. If covered up before this air has been expelled it will blister and give no end of trouble, and be very hard to lay down. After this go over the wall a second time, laying down the material, then thin up stuff on board and go over the wall a third time, finishing as near as possible, using damp brush and trowel. Brush off lightly with a damp brush and do not drench with water, as that would take the face off and kill the material. Work top and bottom together.

In applying float finishes, lay on with trowel and then use float, bringing the work to a true and even surface. Use as little water as possible, so as to avoid killing the surface. These float finishes may be applied while the work is still *green* or *half dry*.

Summer Work.—In hot, dry weather, especially if windy, close all openings in building while plastering to prevent the drying out of material before chemical action has taken place, or, in other words, before it has set. In cases where this has occurred, however, the difficulty is easily remedied by wetting thoroughly with clean water until the material has taken enough water to set it.

Winter Work.—Keep the building in which you are working just above the freezing-point while plastering and 24 hours after finishing.

As these directions may vary slightly from the directions of some manufacturers, the plasterer should obtain a set of directions from the manufacturer of the particular brand of plaster he intends to use.

Pulp or Fibre Plasters.—These plasters are made of a composition somewhat similar to the patent or hard plasters, and then have added a wood fibre or pulp instead of sand, as is used in the patent plasters. The fibrous wood gives the plaster elasticity, toughness, lightness, and strength.

The following directions for the working of these plasters are given:

Directions for Using Pulp or Fibre Plaster.—GROUNDS.—Lay grounds $\frac{5}{8}$ inch for both lath and plaster. This will leave $\frac{1}{4}$ inch for mortar after the lath is on.

LATH.—Nail all lath on firmly, with $\frac{1}{4}$ inch space between lath for key or clinch.

MIXING BOXES.—Use one or two tight boxes of convenient size, say $6 \times 3 \times 1$ feet each, placing them on the floor that is to be plastered.

TENDER.—One tender can care for two plasterers. Place scaffold in room ready to do the ceiling first; measure the number of yards in the ceiling, and put plaster in box, using 10 to 12 pounds of plaster for each square yard of ceiling. Each full sack contains 80 pounds. Mix for this room ceiling all at one time (for a common-sized room). Mix for one side wall all in one batch, etc. Mix with clean water until it is alike all through and just as thin as it can be made to stay on the lath. The thinner the mortar is the easier it will work and the better the wall will be. Do not mix the material until the plasterers are ready to use it. Always keep mortar boxes absolutely clean after each batch of mortar, not trying to mix in with a new batch any mortar that has been partially set.

TOOLS.—Plasterers' tools to use are hawk, trowel, float, and darby.

PLASTERERS.—Do your ceiling first. *Skim your trowel over the lath, using a small quantity of material, with a little pressure to push in the clinch,* which on all walls should only go through the lath, and need not lap over the same. Immediately plaster on to $\frac{1}{4}$ inch thick, use darby for angles and corners, and at once float with a firm, even pressure, until ceiling is level, filling all cat-faces, then slick over with the trowel. In one hour this will be in the putty stage, when it can be troweled until as smooth as desired. Do not use the brush and water. All the water needed will work to the surface under the trowel. All labor put on while there is too much moisture is worse than wasted, as it disturbs the set of the mortar.

Next prepare for the side wall. One man on scaffold and one below, as carrying both top and bottom at one and the same time will avoid any joint and give a perfect wall. This room can be finished before leaving it.

SKIM COAT.—This is not needed and only means a waste of material and loss of valuable time, and does not improve the wall. When a skim coat is desired, it can be applied at once, before the first coat has fully set.

If an absolutely white wall is desired, leave the *pulp plaster* under the float, floating until level, and when in putty stage stipple by patting with a rice root brush. When the lath as well as the plaster is fully dried, apply the common lime and plaster of Paris putty coat, or any of the first-class finish coats.

For use on *brick wall* wet the wall thoroughly and have mortar just as thin as possible to handle. Finish as you go.

For use on *metal lath* mix thoroughly, leave as stiff as you can handle.

CORNICES AND MOULDINGS.—Cornices, mouldings, etc., are usually run with a mould made of sheet iron and cut the reverse contour of the mouldings to be run. Strips of wood are tacked around the walls and ceiling to form a guide to run the mould along. These moulds are usually made to set at right angles to the mouldings, thus leaving a space the width of the moulding or cornice at all angles which have to be worked out by hand. If the mould is made to set at an angle of 45°, or a true mitre with the moulding and the mould made to correspond with the profile of the mouldings on this angle, then the mould can be run in close to all angles. Fig. 176 shows how this mould is made and used.

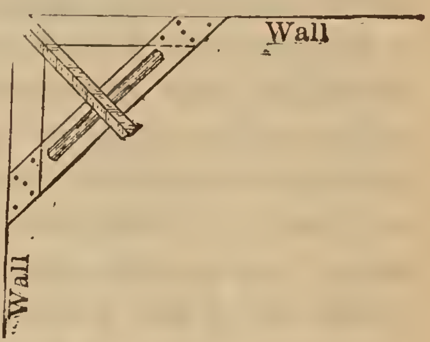

FIG. 176.—Cornice Mould.

STUCCO.—This name is now usually given work done with plaster of Paris, such as cornices, centre pieces, mouldings, etc. All such work should be run before the skim or finish coat of plaster is put on, so the skim coat can be finished up to the cornice or moulding.

The best plaster of Paris should be used for all such work, and should be gauged with enough lime putty or hydrated lime to retard the setting of the plaster to give sufficient time for working.

There are several chemical retarders now on the market for this purpose.

Centre-pieces of leaves, foliage, etc., brackets, and ornaments are usually cast in moulds and stuck in place with soft

plaster of Paris. In addition to the plaster they should be fastened with brass or copper wire holdfasts wherever possible.

Outside Stucco-work.—This is the name usually given to exterior plastering, and is generally done with cement mortar. Care should be taken to keep any outside work from freezing, or from being dried too fast with the heat; it should be shaded to protect it from the sun, and wetting it two or three times a day for several days will improve it.

If the wall to which cement stucco is to be applied is of concrete or brick and presents a rough surface, it should be thoroughly wet and the mortar applied with a trowel, using as much force as possible; but if the wall presents a smooth surface the mortar should be made of a softer consistency and applied by throwing it against the wall by the handfull; this dash coat should be let set before any troweling is done or the second coat applied.

Rough Cast Finish.—If a rough cast finish is desired with the finish coat of stucco it should be applied with a broom made of fine twigs or splints, as follows: Dip the broom in the mortar and stand about 2 feet from the wall, and holding the broom in one hand and a stick in the other, strike the broom against the stick, thus throwing the mortar off the broom on to the wall in a spray giving the desired roughness; this work of course requires some little practice. All stucco-work should be wet several times daily for several days; this will cause a harder finish and prevent streaks from showing between the different days' work.

Scagliola.—This is a material made of plaster and other ingredients to imitate the different marbles. It is used for base, wainscot, columns, etc. The base or first coat of plaster should be of a patent or hard plaster and should have a binder of hair or fibre. After the rough or first coat of plaster is perfectly dry the second coat and colors are then applied. This last coat should be of Keen's cement, or plaster of Paris, mixed with glue-water. After the finish coat and colors are dry, it is polished by rubbing first with pumice stone, then with tripoli (an earthy substance) followed with pulverized charcoal, and finally polished with a rubber of felt dipped in linseed-oil. Scagliola is usually made in slabs and put in place like marble.

Pebble Dash.—The first coat of this work is applied similar to that for rough casting, and after this coat has started to set the second coat is applied, as soft as can be worked. Imme-

diately while this coat is soft the pebbles which have been mixed with cement mortar to give them a cement coating, are thrown against the wall with force enough to imbed them in the mortar. They can also be forced in with the trowel, so as to give a uniform appearance. The pebbles should be imbedded about half their bulk in the mortar. After the mortar has set the entire wall should be given a coat of thin cement wash applied with a brush.

Designs in Pebble Dash.—Designs can be worked out with the pebbles of different sizes or colors by placing them by hand; or panel designs, numbers, etc., can be made as follows: On a board spread a layer of stiff clay, and in this clay press the pebbles about one half their bulk and forming the design in the reverse as desired in the wall. After the design is completed the board and clay in which the pebbles are bedded is placed in the desired position with the projecting pebbles against the soft cement stucco, and pressed firmly against it, so as to press the projecting pebbles into the soft mortar. After the cement mortar hardens for about 48 hours, the clay is washed away from the pebbles leaving the desired design in the wall.

Papier Maché.—This is a composition of paper which has been reduced to a pulp, and mixed with glue, size, or other substance, so that it can be readily cast or moulded in any form desired. It is used for decorating ceilings, walls, etc., and is also prepared for outside use where it should be given several coats of paints to preserve it from the weather.

Carton Pierre.—This is a name given a variety of paper maché which is made especially to imitate stone carving.

Mastic.—Mastic is a plaster for outside use, prepared from ground limestone or cement, sand, and red lead or litharge; all mixed with linseed-oil, the proportions being about as follows: Ground limestone or cement, 5 parts; sand (clean), 5 parts; red lead or litharge, 1 part; boiled linseed-oil, enough to render plastic.

The brick or stone walls to which the mastic is to be applied should receive two heavy coats of boiled oil and let thoroughly dry before the mastic is put on.

Staff.—This composition that has had such an extensive use on recent fair and exposition buildings, is a mixture of plaster of Paris and a suitable binding material, such as manila fibre, hemp, etc.

Staff is a fire-proof material inasmuch as it will withstand

heat and fire to a certain extent. Staff when made and applied correctly and used in moderate climates will prove very durable.

Cold-water Paints.—These paints are made of mixtures of the different colored paint pigments in a powdered form mixed with the casein and albumen taken from skimmed milk. This prepared mixture is sold dry and is prepared for use by the addition of clean water only. It makes a better wash or paint than the ordinary whitewash.

Whitewash.—Common whitewash is made by slaking fresh lime and adding enough water to make a thin paste; by using 2 pounds of sulphate of zinc and 1 pound of salt to each half bushel of lime the whitewash will be much harder and not crack.

A half pint of linseed-oil to each gallon of whitewash will make it more durable for outside work. To color add to each bushel of lime 4 to 6 pounds of ochre for cream color; 6 to 8 pounds amber, 2 pounds Indian red, and 2 pounds of lamp-black for fawn color; 6 to 8 pounds raw umber and 3 or 4 pounds lampblack for buff or stone color.

Estimating Plaster Work.

Lathing.—Wood lathing is usually done by the thousand, but is figured with the plastering at a certain price per square yard. For the covering capacity of wood lath, see page 288.

Metal lath is done by the square yard, and is also figured in along with the plastering.

Plastering.—All flat surfaces, such as walls, ceilings, etc., are figured by the square yard, and price made according to the work done, as two-coat, or three-coat work; sand or hard white finish.

In some parts of the country there is a rule among the plasterers that no deductions will be made for ordinary door or window openings, while in other parts it is a rule to deduct one half of each opening. When plastering is to be paid for by the yard an understanding should be had regarding the measurement before the work is done.

Circle, elliptical, or groined work, round corners, etc., is usually charged extra.

Stucco-work, such as mouldings, cornices, etc., is done by the lineal foot, the price depending on the girth or size of the cornice or moulding. Ornaments, such as centre-pieces, brackets, etc., are charged by the piece, according to their size and enrichment.

Plastering Data.—1 barrel of lime will make about $2\frac{3}{4}$ barrels of paste.

1 barrel of hair weighs about 15 pounds.

1 barrel of lime, 18 cubic feet of sand, and 22 pounds of hair will brown-coat about 40 yards on wooden lath with $\frac{7}{8}$-inch grounds, or about 32 yards on brick or terra-cotta walls with $\frac{5}{8}$-inch grounds, or about 30 yards on wire or metal lath.

1 barrel of lime, 1 barrel of plaster of Paris, 1 barrel white sand will skim-coat about 140 square yards.

First-coat mortar = 1 barrel lime, 18 cubic feet sand, $1\frac{1}{2}$ bushels hair.

Second-coat mortar = 1 barrel lime, $21\frac{1}{2}$ cubic feet sand, $\frac{3}{4}$ bushel hair.

The covering capacity of patent or hard wall plaster varies from 90 to 150 yards per ton.

The pulp or fibre plasters will cover from 130 to 170 yards per ton.

1 barrel of Lafarge cement and 2 of sand will cover about 25 square yards $\frac{3}{8}$ inch thick.

1 ton of Keene's cement will first-coat about 475 yards, or brown-coat and white hard finish about 300 yards, or first and second-coat about 350 yards.

1 bag of 150 pounds of patent soapstone finish will cover about 45 yards.

Plasterers' Tables.—The following tables, giving the number of squarc yards of plaster in rooms of various sizes, have been prepared and copyrighted by the United States Gypsum Company, and are used by special permission of this company, subject to improvements made by the author.

They will be found very valuable in computing the number of square yards of plastering in any room or building; they give the number of square yards and feet in several thousand sized rooms. *Example.*—To obtain the number of square yards in a room 12×15×7 feet, turn to the table giving measurements for rooms with 7 foot ceiling. In the top row of figures find 12, then follow this column down to the line of figures opposite 15 in the left-hand column where we find 62, the answer, or 62 square yards of plastering in the room. When the half foot comes in the dimensions of a room, both ways, take the next largest number on one side. When it comes on one side only add one yard, and it will be close.

NUMBER OF SQUARE YARDS AND FEET IN ROOMS WITH 7 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	10.3																			
4	12.2	14.2																		
5	14.1	16.2	18.3																	
6	16.0	18.2	20.4	22.6																
7	17.8	20.2	22.5	24.8	27.2															
8	19.7	22.2	24.6	27.1	29.5	32.0														
9	21.6	24.2	26.7	29.3	31.8	34.4	37.0													
10	23.5	26.2	28.8	31.5	34.2	36.8	39.5	42.2												
11	25.4	28.2	31.0	33.7	36.5	39.3	42.1	44.8	47.6											
12	27.3	30.2	33.1	36.0	38.8	41.7	44.6	47.5	50.4	53.3										
13	29.2	32.2	35.2	38.2	41.2	44.2	47.2	50.2	53.2	56.2	59.2									
14	31.1	34.2	37.3	40.4	43.5	46.6	49.7	52.8	56.0	59.1	62.2	65.3								
15	33.0	36.2	39.4	42.6	45.8	49.1	52.3	55.5	58.7	62.0	65.2	68.4	71.6							
16	34.8	38.2	41.5	44.8	48.2	51.5	54.8	58.2	61.5	64.8	68.2	71.5	74.8	78.2						
17	36.7	40.2	43.6	47.1	50.5	54.0	57.4	60.8	64.3	67.7	71.2	74.6	78.1	81.5	85.5					
18	38.6	42.2	45.7	49.3	52.8	56.4	60.0	63.5	67.1	70.6	74.2	77.7	81.3	84.8	88.4	92.0				
19	40.5	44.2	47.8	51.5	55.2	58.8	62.5	66.2	69.8	73.5	77.2	80.8	84.5	88.2	91.8	95.5	99.2			
20	42.4	46.2	50.0	53.7	57.5	61.3	65.1	68.8	72.6	76.4	80.2	84.0	87.7	91.5	95.3	99.1	102.8	106.6		
21	44.3	48.2	52.1	55.8	59.8	63.7	67.6	71.5	75.4	79.3	83.2	87.1	91.0	94.8	98.7	102.6	106.5	110.4	114.3	
22	46.2	50.2	54.2	58.2	62.2	66.2	70.2	74.2	78.2	82.2	86.2	90.2	94.2	98.2	102.2	106.2	110.2	114.2	118.2	122.2
23	48.0	52.2	56.3	60.4	64.5	68.6	72.1	76.8	81.0	85.1	89.2	93.3	97.4	101.5	105.6	109.7	113.8	118.0	122.1	126.2
24	50.0	54.2	58.4	62.6	66.8	71.1	75.3	79.5	83.7	88.0	92.2	96.4	100.6	104.8	109.1	113.3	117.5	121.7	126.0	130.2

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOM WITH 7.6 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	11.0																			
4	13.0	15.1																		
5	15.0	17.2	19.4																	
6	17.0	19.3	21.6	24.0																
7	19.0	21.4	23.8	26.3	28.7															
8	21.0	23.5	26.1	28.6	31.2	33.7														
9	23.0	25.6	28.3	31.0	33.6	36.3	39.0													
10	25.0	27.7	30.5	33.3	36.1	38.8	41.6	44.4												
11	27.0	29.8	32.7	35.6	38.5	41.4	44.3	47.2	50.1											
12	29.0	32.0	35.0	38.0	41.0	44.0	47.0	50.0	53.0	56.0										
13	31.0	34.1	37.2	40.3	43.4	46.5	49.6	52.7	55.8	59.0	62.1									
14	33.0	36.2	39.4	42.6	45.8	49.1	52.3	55.5	58.7	62.0	65.2	68.4								
15	35.0	38.3	41.6	45.0	48.3	51.6	55.0	58.3	61.6	65.0	68.3	71.6	75.0							
16	37.0	40.4	43.8	47.3	50.7	54.2	57.6	61.1	64.5	68.0	71.4	74.8	78.3	81.7						
17	39.0	42.5	46.1	49.6	53.2	56.7	60.3	63.8	67.4	71.0	74.5	78.1	81.6	85.2	88.7					
18	41.0	44.6	48.3	52.0	55.6	59.3	63.0	66.6	70.3	74.0	77.6	81.2	85.0	88.6	92.3	96.0				
19	43.0	46.7	50.5	54.3	58.1	61.8	65.6	69.4	73.2	77.0	80.7	84.5	88.3	92.1	95.8	99.6	103.4			
20	45.0	49.8	52.7	56.6	60.5	64.4	68.3	72.2	76.1	80.0	84.8	87.7	91.6	95.5	99.4	103.3	107.2	111.1		
21	47.0	51.0	55.0	59.0	63.0	67.0	71.0	75.0	79.0	83.0	87.0	91.0	95.0	99.0	103.0	107.0	111.0	115.0	119.0	
22	49.0	53.1	57.2	61.3	65.4	69.5	73.6	77.7	81.8	86.0	90.1	94.2	98.3	102.4	106.5	110.6	114.7	118.8	123.0	127.0
23	51.0	55.2	59.4	63.6	67.8	72.1	76.3	80.5	84.7	89.0	93.2	97.4	101.6	105.8	110.1	114.3	118.5	122.7	127.0	131.2
24	53.0	57.3	61.6	66.0	70.3	74.6	79.3	80.5	84.7	89.0	93.2	97.4	101.6	105.3	113.6	118.0	122.3	126.6	131.0	135.3

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOMS WITH 8 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	11.6																			
4	13.7	16.0																		
5	15.8	18.2	20.5																	
6	18.0	20.4	22.8	25.3																
7	20.1	22.6	25.2	27.7	30.3															
8	22.2	24.8	27.5	30.2	32.8	35.5														
9	24.3	27.1	29.8	32.6	35.4	38.2	41.0													
10	26.4	29.3	32.2	35.1	38.0	40.8	43.7	46.6												
11	28.5	31.5	34.5	37.5	40.5	43.5	46.5	49.5	52.5											
12	30.6	33.7	36.8	40.0	43.1	46.2	49.3	52.4	55.5	58.6										
13	32.7	36.0	39.2	42.4	45.6	48.8	52.1	55.3	58.5	61.7	65.0									
14	34.8	38.2	41.5	44.8	48.2	51.5	54.8	58.2	61.5	64.8	68.2	71.5								
15	37.0	40.4	43.8	47.3	50.7	54.2	57.6	61.1	64.5	68.0	71.4	74.8	78.3							
16	39.1	42.6	46.2	49.7	53.3	56.8	60.4	64.0	67.5	71.1	74.6	78.2	81.7	85.3						
17	41.2	44.8	48.5	52.5	55.8	59.5	63.2	66.8	70.5	74.2	77.8	81.5	85.2	88.8	92.5					
18	43.3	47.1	50.8	54.6	58.4	62.2	66.0	69.7	73.5	77.3	81.1	84.8	88.6	92.4	96.2	100.0				
19	45.4	49.3	53.2	57.1	61.0	64.8	68.7	72.6	76.5	80.4	84.3	88.2	92.1	96.0	99.8	103.7	107.6			
20	47.5	51.5	55.5	59.5	63.5	67.5	71.5	75.5	79.5	83.5	87.5	91.5	95.5	99.5	103.5	107.5	111.5	115.4		
21	49.6	53.7	57.8	62.0	66.1	70.2	74.3	78.4	82.5	86.6	90.7	94.8	99.0	103.1	107.2	111.3	115.4	119.5	123.6	
22	51.7	56.0	60.2	64.4	68.8	52.8	77.1	81.3	85.5	89.7	94.0	98.2	102.4	106.6	110.8	115.1	119.3	123.5	127.7	132.0
23	53.8	58.2	62.5	66.8	71.2	75.5	79.8	84.2	88.5	92.8	97.2	101.5	105.8	110.2	114.5	118.8	123.2	127.5	131.8	136.2
24	56.0	60.4	64.8	69.3	73.7	78.2	82.6	87.1	91.5	96.0	100.4	104.8	109.3	113.7	118.2	122.6	127.1	131.5	136.0	140.4

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOM WITH 8.6 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	12.3																			
4	14.5	16.8																		
5	16.7	19.2	21.6																	
6	19.0	21.5	24.1	26.6																
7	21.2	23.8	26.5	29.2	31.8															
8	23.4	26.2	29.0	31.7	34.5	37.3														
9	25.6	28.5	31.4	34.3	37.2	40.1	43.0													
10	27.8	30.8	36.8	39.8	42.8	45.8	48.8	48.8												
11	30.1	33.2	36.3	39.4	42.5	45.6	48.7	51.8	55.0											
12	32.2	35.5	38.7	42.0	45.2	48.4	51.6	54.8	58.1	61.3										
13	34.5	37.8	41.2	44.5	47.8	51.2	54.5	57.8	61.2	64.5	67.8									
14	36.7	40.2	43.6	47.1	50.5	54.0	57.4	60.8	64.3	67.7	71.2	74.6								
15	39.0	42.5	46.1	49.6	53.2	56.7	60.3	63.8	67.4	71.0	74.5	78.1	81.6							
16	41.2	44.8	48.5	52.2	55.8	59.5	63.2	66.8	70.5	74.2	77.8	81.5	85.2	88.8						
17	43.4	47.2	51.0	54.7	58.5	62.3	66.1	69.8	73.6	77.4	81.2	85.0	88.7	92.5	96.3					
18	45.6	49.5	53.4	57.3	61.2	65.1	69.0	72.8	76.7	80.6	84.5	88.4	92.3	96.2	100.1	104.0				
19	47.8	51.8	55.8	59.8	63.8	67.8	71.8	75.8	79.8	83.8	87.8	91.8	95.8	99.8	103.8	107.8	111.8			
20	50.1	54.2	58.3	62.4	66.5	70.6	74.7	78.8	83.0	87.1	91.2	95.3	99.4	103.5	107.6	111.7	115.8	120.0		
21	52.3	56.5	60.7	65.0	69.2	73.4	77.6	81.8	86.1	90.3	94.5	98.7	103.0	107.2	111.4	115.6	119.8	124.1	128.3	
22	54.5	58.8	63.2	67.5	71.8	76.2	80.5	84.8	89.2	93.5	97.8	102.2	106.5	110.8	115.2	119.5	123.8	128.2	132.5	136.8
23	56.7	61.2	65.6	70.1	74.5	79.0	83.4	87.8	92.3	96.7	101.2	105.6	110.1	114.5	119.1	123.4	127.8	132.3	136.7	141.2
24	59.0	63.5	68.1	72.6	77.2	81.7	86.3	90.8	95.4	100.0	104.5	109.1	113.6	118.2	122.7	127.3	131.8	136.4	141.0	145.5

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOMS WITH 9 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	13.0																			
4	15.3	17.7																		
5	17.6	20.2	22.7																	
6	20.0	22.6	25.3	28.0																
7	22.3	25.1	27.8	30.6	33.4															
8	24.6	27.5	30.4	33.3	36.2	39.1														
9	27.0	30.0	33.0	36.0	39.0	42.0	45.0													
10	29.3	32.4	35.5	38.6	41.7	44.8	48.0	52.0												
11	31.6	34.8	38.1	41.3	44.5	47.7	51.0	54.2	57.4											
12	34.0	37.3	40.6	44.0	47.3	50.6	54 0	57.3	60.0	64.0										
13	36.3	39.7	43.2	46.6	50.1	53.5	57.0	60.4	63.8	67.3	70.7									
14	38.6	42.2	45.7	49.3	52.8	56.4	60.0	63.5	67.1	70.6	74.2	77.7								
15	41.0	44.6	48.3	52.0	55.6	59.3	63.0	66.6	70.3	74.0	77.6	81.3	85.0							
16	43.3	47.1	50.8	54.6	58.4	62.2	66.0	69.7	73.5	77.3	81.1	84.8	88.6	92.4						
17	45.6	49.5	53.4	57.3	61.2	65.1	69.0	72.8	76.7	80.6	84.5	88.4	92.3	96.2	100.4					
18	48.0	52.0	56.0	60.0	64.0	68.0	72 0	76.0	80.0	84.0	88.0	92.0	96.0	100.0	104.0	108.0				
19	50.3	54.4	58.5	62.6	66 7	70.8	75.0	79.1	83.2	87.3	91.4	95.5	99.6	103.7	107.8	112.0	116.1			
20	52.6	56.8	61.1	65.3	69.5	73.7	78.0	82.2	86.4	90.6	94.8	99.1	103.3	107.5	111.7	116.0	120.2	124.4		
21	55.0	59.3	63.6	68.0	72.3	76.6	81.0	85.3	89.6	94.0	98.3	102.6	107.0	111.3	115.6	120.0	124.3	128.6	134.3	
22	57.3	61.7	66.2	70.6	75.1	79.5	84.0	88.4	92.8	97.3	101.7	106.2	111.6	115.1	121.5	124.0	128.4	132.8	137.3	141.7
23	59.6	64.2	68.7	73.3	77.8	82.4	87.0	91.5	95.1	100.6	105.2	109.7	114.3	118.8	123.4	128.0	132.5	137.0	141.6	146.2
24	62.0	66.6	71.3	76.0	80.6	85.3	90.0	94.6	99.3	104.0	108.6	113.3	118.0	122.6	127.3	132.0	136.6	141.3	146.0	150.6

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOMS WITH 9.6 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	13.6																			
4	16.1	18.6																		
5	18.5	21.2	23.8																	
6	21.0	23.7	26.5	29.3																
7	23.4	26.3	29.2	32.1	35.0															
8	25.8	28.8	31.8	34.8	37.8	40.8														
9	28.3	31.4	34.5	37.6	40.7	43.8	47.0													
10	30.7	34.0	37.2	40.4	43.6	46.8	50.1	53.3												
11	33.2	36.5	39.8	43.2	46.5	49.8	53.2	56.5	59.8											
12	35.6	39.1	42.5	46.0	49.4	52.8	56.3	59.7	63.2	66.5										
13	38.1	41.6	45.2	48.7	52.3	55.8	59.4	63.0	66.5	70.1	73.6									
14	40.5	44.2	47.8	51.5	55.2	58.8	62.5	66.2	69.8	73.5	77.2	80.8								
15	43.0	46.7	50.5	54.3	58.1	61.8	65.6	69.4	73.2	77.0	80.7	84.5	88.3							
16	45.4	49.3	53.2	57.1	61.0	64.8	68.7	72.6	76.5	80.4	84.3	88.2	92.1	96.0						
17	47.8	51.8	55.8	59.8	63.8	67.8	71.8	75.8	79.8	83.8	87.8	91.8	95.8	99.8	103.8					
18	50.3	54.4	58.5	62.6	66.7	70.8	75.0	79.1	83.2	87.3	91.4	95.5	99.6	103.7	107.8	112.0				
19	52.7	57.0	61.2	65.4	69.6	73.8	78.1	82.3	86.5	90.7	95.0	99.0	103.4	107.6	111.8	116.1	120.3			
20	55.2	59.5	63.8	68.2	72.5	76.8	81.2	85.5	89.8	94.2	98.5	102.8	107.2	111.5	115.8	120.2	124.5	128.8		
21	57.6	62.1	66.5	71.0	75.4	79.8	84.3	88.7	93.2	97.6	102.1	106.5	111.0	115.4	119.8	124.3	128.7	133.2	137.6	
22	60.1	64.6	69.2	73.7	78.3	82.8	87.4	92.0	96.5	101.1	105.6	110.2	114.7	119.3	123.8	128.4	133.0	137.5	142.1	146.6
23	62.5	67.2	71.8	76.5	81.2	85.8	90.5	95.2	99.8	104.5	109.2	113.8	118.5	123.2	127.8	132.5	137.2	141.8	146.5	151.2
24	65.0	69.7	74.5	79.3	84.1	88.8	93.6	98.4	103.2	108.0	112.7	117.5	122.3	127.1	131.8	136.6	141.4	146.2	151.0	155.7

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOMS WITH 10 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	14.3																			
4	16.8	19.5																		
5	19.4	22.2	25.0																	
6	22.0	24.8	27.7	30.6																
7	24.5	27.5	30.5	33.5	36.5															
8	27.1	30.2	33.3	36.4	39.5	42.6														
9	29.6	32.8	36.1	39.3	42.5	45.7	49.0													
10	32.3	35.5	38.8	42.2	45.5	48.8	52.2	55.5												
11	34.7	38.2	41.6	45.1	48.5	52.0	55.4	58.8	62.3											
12	37.3	40.8	44.4	48.0	51.5	55.1	58.6	62.2	65.7	69.3										
13	39.8	43.5	47.2	50.8	54.5	58.2	61.8	65.5	69.2	72.8	76.5									
14	42.4	46.2	50.0	53.7	57.5	61.3	65.1	68.8	72.6	76.4	80.2	84.0								
15	45.0	48.8	52.7	56.6	60.5	64.4	68.3	72.2	76.1	80.0	83.8	87.7	91.6							
16	47.5	51.5	55.5	59.5	63.5	67.5	71.5	75.5	79.5	83.5	87.5	91.5	95.5	99.5						
17	50.1	54.2	58.3	62.4	66.5	70.6	74.7	78.8	83.0	87.1	91.2	95.3	99.4	103.5	107.6					
18	52.6	56.8	61.1	65.3	69.5	73.7	78.0	82.2	86.4	90.6	94.8	99.1	103.3	107.5	111.7	116.0				
19	55.2	59.5	63.8	68.2	72.5	76.8	81.2	85.5	89.8	94.2	98.5	102.8	107.2	111.5	115.8	120.2	124.5			
20	57.7	62.2	66.6	71.1	75.5	80.0	84.4	88.8	93.3	97.7	102.2	106.6	111.1	115.5	120.0	124.4	128.8	133.3		
21	60.3	64.8	69.4	74.0	78.5	83.1	87.6	92.2	96.7	101.3	105.8	110.4	115.0	119.5	124.1	128.6	133.2	137.7	142.3	
22	62.8	67.5	72.2	76.8	81.5	86.2	90.8	95.5	100.2	104.8	109.5	114.2	118.8	123.5	128.2	132.8	137.5	142.2	146.8	151.5
23	65.4	70.2	75.0	79.7	84.5	89.3	94.1	98.8	103.6	108.4	113.2	118.0	122.7	127.5	132.3	137.1	141.8	146.6	151.4	156.2
24	68.0	72.8	77.7	82.6	87.5	92.4	97.3	102.2	107.1	112.1	114.8	121.8	126.6	131.5	136.4	141.3	146.2	151.1	156.0	160.8

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOMS WITH 10.6 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	15.0																			
4	17.6	20.4																		
5	20.3	23.2	26.1																	
6	23.0	26.0	29.0	32.0																
7	25.6	28.7	31.8	35.0	38.1															
8	28.3	31.5	34.7	38.0	41.2	44.4														
9	31.0	34.3	37.6	41.0	44.3	47.6	51.0													
10	33.6	37.1	40.5	44.0	47.4	50.8	54.3	57.7												
11	36.3	39.8	43.4	47.0	50.5	54.1	57.6	61.2	64.7											
12	39.0	42.6	46.3	50.0	53.6	57.3	61.0	64.6	68.3	72.0										
13	41.6	45.4	49.2	53.0	56.7	60.5	64.3	68.1	71.8	75.6	79.4									
14	44.3	48.2	52.1	56.0	59.8	63.7	67.6	71.5	75.4	79.3	83.2	87.1								
15	47.0	51.0	55.0	59.0	63.0	67.0	71.0	75.0	79.0	83.0	87.0	91.0	95.0							
16	49.6	53.7	57.8	62.0	66.1	70.2	74.3	78.4	82.5	86.6	90.7	94.8	99.0	103.1						
17	52.3	56.5	60.7	65.0	69.2	73.4	77.6	81.8	86.1	90.3	94.5	98.7	103.0	107.2	111.4					
18	55.0	59.3	63.6	68.0	72.3	76.6	81.0	85.3	89.6	94.0	98.3	102.6	107.0	111.3	115.6	120.0				
19	57.6	62.1	66.5	71.0	75.4	79.8	84.3	88.7	93.2	97.6	102.1	106.5	111.0	115.4	119.8	124.3	128.7			
20	60.3	64.8	69.8	74.0	78.5	83.1	87.6	92.2	96.7	101.3	105.8	110.4	115.0	119.5	124.1	128.6	133.2	137.7		
21	63.0	67.6	72.3	77.0	81.6	86.3	91.0	95.6	100.3	105.0	109.6	114.3	119.0	123.6	128.3	133.0	137.6	142.3	147.0	
22	55.6	70.4	75.2	80.0	84.7	89.5	94.3	99.1	103.8	108.6	113.4	118.2	123.0	127.7	132.5	137.3	142.1	146.8	151.6	156.4
23	68.3	73.2	78.1	83.0	87.8	92.7	97.6	102.5	107.4	112.3	117.2	122.1	127.0	131.8	136.7	141.6	146.5	151.4	156.3	161.2
24	71.0	76.0	81.0	86.0	91.0	96.0	101.0	106.0	111.0	116.0	121.0	126.0	131.0	136.0	141.0	146.0	151.0	156.0	161.0	166.0

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOMS WITH 11 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	15.6																			
4	18.4	21.3																		
5	21.2	24.2	27.2																	
6	24.0	27.1	30.2	33.3																
7	26.7	30.0	33.2	36.4	39.6															
8	29.5	32.8	36.2	39.5	42.8	46.2														
9	32.3	35.7	39.2	42.6	46.1	49.5	53.0													
10	35.1	38.6	42.2	45.7	49.3	52.8	56.4	60.0												
11	37.8	41.5	45.2	48.8	52.5	56.2	59.8	63.5	67.2											
12	40.6	44.4	48.2	52.0	55.7	59.5	63.3	67.1	70.8	74.6										
13	43.4	47.3	51.2	55.1	59.0	62.8	66.7	70.6	74.5	78.4	82.3									
14	46.2	50.2	54.2	58.2	62.2	66.2	70.2	74.2	78.2	82.2	86.2	90.2								
15	49.0	53.1	57.2	61.3	65.4	69.5	73.6	77.7	81.8	86.0	90.1	94.2	98.3							
16	51.7	56.0	60.2	64.4	68.6	72.8	77.1	81.3	85.5	89.7	94.0	98.2	102.4	106.6						
17	54.5	58.8	63.2	67.5	71.8	76.2	80.5	84.8	89.2	93.5	97.8	102.2	106.5	110.8	115.2					
18	57.3	61.7	66.2	70.6	75.1	79.5	84.0	88.4	92.8	97.3	101.7	106.2	110.6	115.1	119.5	124.0				
19	60.1	64.6	69.2	73.7	78.3	82.8	87.4	92.0	96.5	101.1	105.6	110.2	114.7	119.3	123.8	128.4	133.0			
20	62.8	67.5	72.2	76.8	81.5	86.2	90.8	95.5	100.2	104.8	109.5	114.2	118.8	123.5	128.2	132.8	137.5	142.2		
21	65.6	70.4	75.2	80.0	84.7	89.5	94.3	99.1	103.8	108.6	113.4	118.2	123.0	127.7	132.5	137.3	142.1	146.8	151.6	
22	68.4	73.3	78.2	83.1	88.0	92.8	97.7	102.6	107.5	112.4	117.3	122.2	127.1	132.0	136.8	141.7	146.6	151.5	156.4	161.3

The amount indicated includes side walls and ceilings.

NUMBER OF SQUARE YARDS AND FEET IN ROOMS WIH 12 FOOT CEILINGS.

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
3	17.0																			
4	20.0	23.1																		
5	23.0	26.2	29.4																	
6	26.0	29.3	32.6	36.0																
7	29.0	32.4	35.8	39.3	42.7															
8	32.0	35.5	39.1	42.6	46.2	49.7														
9	35.0	38.6	42.3	46.0	49.0	53.3	57.0													
10	38.0	41.7	45.5	49.3	53.0	56.8	60.6	64.4												
11	41.0	44.8	48.7	52.6	56.5	60.4	64.3	68.2	72.1											
12	44.0	48.0	52.0	56.0	60.0	64.0	68.0	72.0	76.0	80.0										
13	47.0	51.1	55.2	59.3	63.4	67.5	71.6	75.7	79.8	84.0	88.1									
14	50.0	54.2	58.4	62.6	66.8	71.1	75.3	79.5	83.7	88.0	92.2	96.4								
15	53.0	57.3	61.6	66.0	70.3	74.6	79.0	83.3	87.6	92.0	96.3	100.6	105.0							
16	56.0	60.4	64.8	69.3	73.7	78.2	82.6	87.1	91.5	96.0	100.4	104.8	109.3	113.7						
17	59.0	63.5	68.1	72.6	77.2	81.7	86.3	90.8	95.4	100.0	104.5	109.1	113.6	118.2	122.7					
18	62.0	66.6	71.3	76.0	80.6	85.3	90.0	94.6	99.3	104.0	108.6	113.3	118.0	122.6	127.3	132.0				
19	65.0	69.7	74.5	79.3	84.1	88.8	93.6	98.4	103.2	108.0	112.7	117.5	122.3	127.1	131.8	136.6	141.4			
20	68.0	72.8	77.7	82.6	87.5	92.4	97.3	102.2	107.1	112.0	116.8	121.7	126.6	131.5	136.4	141.3	146.2	151.1		
21	71.0	76.0	81.0	86.0	91.0	96.0	101.0	106.0	111.0	116.0	121.0	126.0	131.0	136.0	141.0	146.0	151.0	156.0	161.0	
22	74.0	79.1	84.2	89.3	94.4	99.5	104.6	109.7	114.8	120.0	125.1	130.2	135.3	140.4	145.5	150.6	155.7	160.8	166.0	171.1

The amount indicated includes side walls and ceilings.

PART VII.

RULES FOR SUPERINTENDING CONCRETE CONSTRUCTION, TABLES OF STRENGTH, WEIGHT, ETC., MISCELLANEOUS TABLES, VARIOUS RECEIPTS, HINTS, ETC., MENSURATION TABLES, A FEW PROBLEMS FOR THE NOON HOUR.

Rules for Superintending Concrete Construction.—Forms.—As the forms are being built, see that they are built strong enough and so braced and tied together that they will hold the mass of wet concrete to be deposited in them, and withstand the pressure caused by puddling and tamping, and not bulge or give way with the pressure.

For forms use pine, spruce, or fir lumber. Some other woods, especially California redwood and chestnut, will stain the face of the concrete.

The forms should usually be left in place for about 10 days, or until the concrete is hard, or in the case of walls with a pressure on them, or columns, beams, etc., the forms should not be removed under 3 or 4 weeks, and in cold weather should be left in place two months or more.

When the conditions will allow and it is intended to remove the forms while the concrete is green, or before it is about a week old, the forms should be bolted and fastened together, so they can be taken down without jarring the concrete and cracking or chipping it.

When a smooth surface is desired on the concrete use tongued and grooved boards for forms. To prevent bulging the boards should be not less than $1\frac{1}{2}$ inches in thickness.

The forms should be made nearly water-tight, and all knot holes and cracks should be covered with a piece of tin to prevent the concrete from running out.

Before depositing any concrete, go over the forms, and check them up as to size, etc., and see that all chases, recesses, openings for pipes, bearing recesses, etc., have been built in the forms, so as to give the desired space or pocket in the concrete.

See that the forms or center for arches are set on wedges, which can be driven out and the center lowered when desired to remove it.

All stay bolts in the forms, which will be covered with the concrete should be well greased before the concrete is deposited, so the bolts can be withdrawn easily when the forms are taken down.

The forms for beams should be made with a little camber, so that the weight of the concrete will not cause the forms to sag below a straight line.

As the concrete is being put in place watch the forms for breaking or bulging.

On work where it is intended to remove the forms as soon as possible in order to finish the face of the concrete, the forms should be given a coat of linseed-oil or crude oil before the concrete is put in place. Boiled linseed-oil is the best, as it gives a glazed or varnished surface to the forms.

Do not use very dry lumber for forms; it will swell and warp. Wet or green lumber makes the best forms.

Do not allow the use of small wire for tying together forms where there will be much pressure of the wet concrete; the wire will cut into the wood and allow the forms to spread. Use bolts where there will be much strain on the forms.

Materials.—See that the materials used are exactly what are called for in the specifications, and that each material will meet the specification requirements.

See that the aggregate is clean and of the kind and size specified. If it contains much stone dust, it indicates a rotten stone and should not be used unless tested.

The stone should be of about one size or be evenly graded from fine to coarse. Too much fine stone in the aggregate is detrimental to the strength of the concrete.

All of the very fine materials should be screened out.

Do not use gravel in which much slime and vegetable matter is present.

Do not use larger than $\frac{7}{8}$ inch aggregate for reinforced-concrete work. Larger than this will not pack readily among the reinforcing bars.

Examine the sand as to grit, size, and for earthy or vegetable matter. If containing over 10 per cent of clay it should not be used.

If ocean sand is used in concrete where an efflorescence will disfigure it, the sand should be thoroughly washed to take out the salt.

Do not use "quicksand" (sand that is worn round) for making concrete.

The coarser the stone used the coarser the sand should be, or for dense work, the sand can be graded from fine to coarse.

When the aggregate used is of a small size, the sand should be fine to make dense work.

The cement, if not of a well known and tested brand, should be tested before being used on any important piece of concrete work.

See that the cement before being used is kept protected from the weather and moisture.

Do not use salt water for mixing concrete if it is desired to show no efflorescence.

Do not use puzzolan cement for work above ground and exposed to the dry air or sun.

MEASURING THE MATERIALS.—A quick and exact method of measuring the dry materials for making concrete is with bottomless boxes, as described on page 50.

Barrels with the heads knocked out can also be used for measuring the dry materials, but require a little more labor to shovel the materials into them.

For ordinary work wheelbarrows will do for measuring, provided the workmen can be trusted or some one is watching them all the time; but for exact quantities, the boxes described are the best. When wheelbarrows are used for measuring, first find out the number of bags of cement a barrow will contain, so as to ascertain the number of barrows of sand and aggregate to use to a given number of bags of cement.

Several makes of mixers measure the dry materials auto-

matically, but they should be checked up every day to see that they are operating correctly.

Water can be measured by the bucket, or a good automatic apparatus for measuring the water is described on page 152.

MIXING.—If the mixing is done by hand it should be on a watertight platform with a curb or rim around it to prevent the water running off and carrying away the cement.

See that the mass is mixed dry until it is of a uniform color, before adding the water.

After the water is added, the mixing should be continued until the mass is of the same consistency throughout, and every piece of the aggregate has a coating of the cement mortar.

After ascertaining the amount of water required to the batch, have the water added by measurement so that each batch will be of the same consistency. The author has used the automatic feed mixers, but does not favor them, as the cement feed often becomes clogged and will not measure correctly, and there is no way to measure the water, as in a batch mixer.

Of the various mixers in use a batch mixer is the best, as the materials can be measured exactly for each batch of concrete, and each batch can be mixed as long as desired.

After having found the number of revolutions required to produce a mix as desired, have each and every batch then given that number of revolutions in the mixer.

If the mixing is done in a continuous or gravity mixer, have the dry materials measured in a three-layer pile, first the aggregate, next the sand, and then the cement, by using three bottomless boxes, as described on page 50. Then shovel in the dry mixture, shoveling from the bottom of the layer of aggregate. In this way the dry materials will mix as the cement and sand runs down the face of the pile as it is shoveled in.

If an automatic self-measuring mixer is used, check its measurement at intervals to see the feed has not been changed.

Do not allow the dry materials to be mixed and stand any length of time before being wet and used. The sand generally contains enough moisture to cause the cement to set.

The concrete to be deposited around reinforcing rods should be a mushy mixture that can be puddled into place.

METAL REINFORCING.—See that all rods used for reinforcement are free from rust scales which will prevent the concrete from obtaining a hold on the rod. A thin coating of rust

that has not commenced to scale will not be a detriment, unless the reinforcement is to be used in cinder concrete. For use in cinder concrete, the reinforcement should be galvanized or painted to protect it from the action of the acids in the cinders.

Any rods having rust heavy enough to scale should not be used unless they are cleaned by brushing with wire brushes, or by being dipped in an acid bath to remove the rust.

A pickling bath, which will remove the rust, is made of 1 part sulphuric acid to 5 parts of water. After passing through this bath the rods should be washed in clean water to remove all acid.

Before depositing the concrete see that all reinforcing rods are in their proper places and anchored and tied together, as called for by the specifications. Also check up all rods to see that they are of the same size and in the position indicated on the drawings.

All rods of beams, etc., should have the ends turned to form an anchor in the concrete, and the rods should be spaced so there will be at least 1½ inches of concrete between the rod and the form, and between the different parallel rods there should be about 4 inches of concrete.

When bending reinforcing rods make the bends slowly, as by making a quick or sudden bend the cold bar is more liable to break or crack.

Examine all bends and angles for cracks before placing the rod in position.

When expanded metal or woven wire is used as a reinforcement, see that it is kept up from the soffit of the slab about ¾ inch. If the workmen are not watched they will usually get this reinforcing down so it will be exposed on the bottom of the slab.

Be careful to protect all reinforcing rods which project out of newly deposited concrete, so they will not be struck or jarred, thus breaking the adhesion between the rod and the concrete.

When using any expanded metal or woven wire reinforcing in floor slabs do not permit of the metal being cut and lapped between the beams, but have all splices made on top of a beam, and have the metal sheets lap each other one mesh and wired together.

When depositing concrete around lattice or open columns

or girders fill the interior solid with concrete or cement mortar to prevent rusting.

Depositing the Concrete.—Before depositing any concrete check up the forms as to size, etc., as previously explained. Then see that all sawdust, shavings, chips, etc., are removed and the forms free from all dirt.

It is a good idea to wet the forms thoroughly before the concrete is put in them.

As the concrete is deposited watch as it is puddled or rammed into place to see that it is of the right consistency, and is readily forced into place, filling all spaces solid.

When depositing concrete in beams and such places pound the sides of the forms with a heavy hammer, as this jar will settle the concrete and help to break and force out air bubbles.

Do not dump concrete over 5 feet, it causes the aggregate to separate from the mortar, and the jar of the falling concrete is liable to strain the forms or crack the concrete already in place and set.

When depositing with a bucket lower the bucket as close as possible to the concrete before dumping, and be careful not to let the bucket swing and strike or jar the forms or the finished concrete.

Deposit the concrete in horizontal layers of about 8 inches and ram or puddle each layer thoroughly.

Put on each succeeding layer before the one below has set so the concrete will be one mass with no joints between the layers as deposited.

When depositing concrete in trenches containing water, bail out as much of the water as possible, then deposit the concrete from one end of the trench, driving what water is left to the other end. When water is gathered in this way, take it up by depositing some dry concrete.

When concrete is be deposited under water, use bags or pipe, as explained on page 200.

Have rammers of different sizes on the work, so as to be able to ram the concrete in all places.

Prepare the top of the concrete finished at the close of the day to bond with the concrete that will be deposited on it the next day or after the concrete in place is set. A good method is to scatter some of the stone aggregate over the wet concrete after it is rammed and lightly tamp them in the soft concrete, so that about half of each piece of aggregate is buried

in the concrete and the other half is sticking up to be imbedded in the concrete to be deposited when work is resumed. Another good method is to take a rammer about 4×4 inches and go over the soft concrete, forcing the rammer into it about 2 inches deep once to every foot of surface, thus making a number of holes or indentations in the soft concrete. The next layer of concrete will fill these indentations and dowel the two layers of concrete together. If the concrete used is too soft to hold the indentations made, a number of wood blocks can be forced into the concrete and left in place until the next morning, when they can be taken out before depositing any concrete.

When depositing concrete around reinforcing rods see that the rods are not knocked out of position and that the concrete is packed solid around the rod.

Do not allow a lot of the aggregate free from mortar to gather around the rod, but see that the mortar comes in contact with the rods over their entire surface.

Do not allow any concrete to stand after being mixed, but have it put in place immediately. Some cements attain their initial set in about half an hour after being wet.

When putting concrete fire-proofing around beams take pains to have the concrete forced under the beam, so the space beneath will be filled solid.

See that the workmen when leveling off the concrete as it is deposited do not scrape it with the point of the shovel, thus scraping a lot of the aggregate out of the mortar and depositing it with no mortar in one place. Have the work leveled by spading and shoveling the concrete from the high into the low places, taking mortar and aggregate at each shovelful.

Do not deposit any fresh concrete on concrete that has been in place and set until the surface of the concrete in place has been washed clean. Then to make a better bond or adhesion, give it a coat of cement grout just before depositing the new lot of concrete.

See that all bolts, anchors, nailing-blocks, etc., which may be required in the finished work are put in place and built in as the concrete is deposited. Wood blocks when bedded in concrete should be dipped in hot asphalt to prevent rot.

When putting concrete filling on top of floor slabs or around floor sleepers, see that all dust and dirt is brushed off the con-

crete in place and that it is drenched thoroughly before depositing the filling.

Where required, see that bolts or anchors are built in as the work progresses, for hanging shafting, machinery, etc.

When depositing concrete in girders, floors, etc., commence at the farthest point from the elevator or hoist and work toward the hoist.

In this way it will not be necessary to wheel loaded barrows or to have the workmen walk over the freshly deposited concrete before it is set hard.

When depositing concrete in column forms see that there are no washers or other obstructions in the way of the falling concrete, which would interfere with packing the concrete. Washers are often used on the vertical rods to keep them away from the forms, but these washers prevent the concrete from falling and often on the removal of the forms there is found a cavity under the washer, where the concrete did not fill.

General Notes.—A good tool to use for puddling concrete is a spading fork, which is usually made the shape of a spade but with four or more prongs.

Have all finished concrete wet thoroughly twice daily for a week or more after being put in place.

When casting large blocks of concrete which are to be set as blocks of stone, see that lewis holes are cast in the stone or blocks, so they can be lifted with the derrick. These holes should be on the top "bed."

Do not try to do concrete work when the thermometer is below the freezing-point, unless provision is made to keep the concrete from freezing.

After a concrete gang has been "broke in," keep them at the same work daily. Better and more work is obtained than by changing men frequently.

On important work there should be an inspector at the mixer all the time. Workmen may get careless and make a weak batch of concrete if no one is watching, and this one batch of weak concrete may endanger the whole structure in which it is used. On a piece of work under the supervision of the author a batch of concrete was made and being deposited when he noticed it was "off color."

On examination it was found the men at the mixer had "forgot" to put in the cement.

An accident could be the only result if a batch of such concrete would find its way into a beam or column.

When supervising concrete work take no person's word for anything, but see for yourself, and then be sure you are not being deceived.

In long continuous walls see that expansion joints are provided every 50 or 60 feet.

Do not permit walking or working on floor slabs or beams while the concrete is hardening, as the vibration will loosen the adhesion of the reinforcement and the concrete. If possible, keep newly laid concrete free from traffic of any kind for two or three days.

When removing forms take everything apart as carefully as possible and do not drop timbers, etc., on the floor below, which may cause a crack in the floor slabs or beams.

When constructing sidewalks see that all roots of trees are removed before depositing the concrete, as they will cause cracks by upheaval.

When laying sidewalks do not allow the joints to become filled with cement after being cut through, thus defeating the purpose for which they were cut.

Keep newly laid sidwalks covered or so protected that dogs cannot walk over and disfigure them before the cement is hardened; if necessary keep a man in charge to keep animals and persons from walking over the newly laid walk.

To clean dirt and sawdust out of forms use compressed air or steam when possible, steam being preferable as it blows out the dirt and wets the forms at the same time.

When placing concrete do not dump directly into place but back a little on that already in place, then by puddling and shoving cause the newly dumped concrete to run or flow down into the beams or floor slabs.

Do not try to use oil paint on wet concrete, wait until it is dry before painting.

STRENGTH AND WEIGHT OF VARIOUS GRANITES.

State.	Location.	Strength per Sq. Inch.	Weight per Sq. Foot.
Arkansas	Pulaski Co. (gray granite).........	14,000	...
"	Fourth Mountain (syenite)........	30,740	167
California.......	Rocklin..........................	30,740	167
Colorado	Gunnison..........................	12,976	165
"	Platte Canyon (red)..............	14,585	168
Connecticut.....	Middleton.........................	21,460	...
"	Waterford.........................	23,510	...
"	Meriden (trap rock)...............	34,920	...
"	Kirkland rocks....................	35,000	166
"	Lord's Island.....................	24,000	...
"	Mystic River......................	22,250	164
"	New Haven.........................	9,750	...
"	Millstown Point	16,157	169
"	Milford...........................	22,600	...
"	New London........................	12,500	166
Georgia.........	Lithonia..........................	25,630	...
Maine...........	Hurricane Isle....................	19,538	167
"	Jonesboro (red)...................	24,507	...
"	Waldoboro (white).................	23,111	...
"	North Jay (red)...................	22,367	...
"	Dix Island........................	15,000	166
"	Fox Island (blue).................	15,000	164
"	Sharkey's Quarry..................	22,125	170
"	Vinalhaven (gray).................	17,000	...
Massachusetts....	Cape Ann..........................	20,296	164
"	Milford (pink)....................	30,888	...
"	Milford (Norcross Bros.)..........	20,883	...
"	Quincy (dark).....................	17,750	166
"	Quincy (light)....................	14,750	166
"	Fall River (gray).................	15,937	...
Michigan........	Huron Island......................	18,125	164
Missouri........	Graniteville......................	24,181	...
Minnesota.......	East St. Cloud....................	28,000	168
"	Duluth (dark).....................	17,631	175
"	Duluth (light)....................	19,000	...
New Hampshire ..	Troy..............................	17,950	168
" ..	Keene (blue gray).................	12,000	166
New York.......	Goshen............................	23,500	...
"	Staten Island (blue)..............	22,250	178
"	Tarrytown.........................	18,250	162
New Jersey.....	Scotch Plains (trap rock).........	17,950	...
"	Passaic Co. (gray)................	24,040	...
"	Jersey City.......................	20,750	189
Rhode Island....	Westerly (gray)...................	17,500	165
South Carolina...	Carlisle..........................	29,150	...
Texas..........	Burnet Co.........................	11,891	176
Vermont........	Barre (dark)......................	19,975	...
"	Barre (light).....................	17,856	...
Virginia........	Peters............................	25,100	...
"	Richmond..........................	25,520	...

STRENGTH AND WEIGHT OF SANDSTONES.

State.	Location.	Color.	Strength per Sq. Inch.	Weight per Sq. Foot.
Arizona	Flagstaff	Chocolate	5,857	142
California	Colusa		8,880	...
Colorado	St. Vrains	Red	11,500	149
"	Fort Collins	Gray	11,707	140
"	Manitou	Red	11,000	140
Connecticut	Portland		10,871	148
"	Middletown	Brown	6,950	...
"	Cromwell		16,890	156
Indiana	Riverside	Gray	6,000	...
"	"	Blue	6,090	...
Iowa	La Grande		6,805	...
Kansas	Valley Falls		7,500	152
Kentucky	Langford		15,160	...
Massachusetts	East Longmeadow	Red	11,595	154
Missouri	Warrensburg	Blue-gray	9,687	149
Minnesota	Kasota	Pink	10,700	164
"	Kettle River	Pinkish buff	17,000	139
"	Frontenac	Buff	6,250	145
Michigan	Redrock		6,019	...
"	Portage Entry (Lake Superior)	Red	6,776	126
"	Marquette		7,450	158
New York	Potsdam	Red	18,401	162
" "	Medina	Pink	17,250	150
" "	Oxford	Blue	12,677	...
" "	Warsaw	Blue	19,968	167
" "	Albion	Brown	13,500	157
" "	Little Falls	Brown	9,850	...
" "	Haverstraw	Red	4,350	133
New Jersey	Belleville	Gray	11,700	147
" "	"	Brown	13,310	148
North Carolina	Carthage		12,750	...
Ohio	Seneca	Reddish brown	5,000	134
"	Lancaster		5,950	...
"	Amherst	Buff	9,450	133
"	Berea	Dark drab	9,510	134
"	Cleveland	Olive-green	6,800	140
"	Vermillion	Drab	8,850	135
"	Massilon	Yellow-drab	8,750	...
Pennsylvania	Hummelstown	Brown	13,097	...
"	Laurel Run		22,250	166
"	White Haven		29,250	...
South Dakota	Hot Springs		6,914	...
" "	Rapid City	Gray	11,452	...
" "	" "	Red	6,116	...
Washington	Chuckanut		10,276	...
Wisconsin	Fon du Lac	Purple	6,237	138
Wyoming	Rawlins		10,883	...

RATIO OF ABSORPTION OF STONES.

Kind of Material.	Maximum.	Minimum.	Average.	Kind of Material.	Maximum.	Minimum.	Average.
Granites	1/150	0	1/750	Sandstones	1/15	1/240	1/24
Marbles	1/150	0	1/300	Bricks	1/4	1/50	1/10
Limestones	1/20	1/500	1/38	Mortars	1/2	1/10	1/4

Strength and Weight of Various Limestones.

State.	Location.	Strength per Sq. Inch.	Weight per Cu. Foot.	State.	Location.	Strength per Sq. Inch.	Weight per Cu. Foot.
Ark. . .	Johnston.	15,500	. . . .	Mich.	Lime Island. . . .	18,000	. . . .
Ill. . . .	Kankakee.	13,544	165	Mo. . .	Carthage (white)	14,950	185
" . . .	Joliet (white) . .	14,775	160	"	Cooper Co. (dark drab).	6 650	141
" . . .	Quincy.	9.687	160	N. Y.	Glens Falls.	11,475	168
" . . .	Grafton.	17,000	. . . .	"	Lake Champlain	25,000	171
Ind. . .	Bedford.	6,000	154	"	North River. . . .	11,475	169
" . . .	Bloomington. . .	4,100	. . . .	"	Canajoharie. . . .	20,700	168
" . . .	Salem.	9,000	156	"	Erie Co. (blue). .	12,250	165
" . . .	Stinsville	5,600	. . . .	"	Kingston	13,900	168
Iowa. .	La Grande.	10,825	. . . .	"	Garrison.	18,500	165
" . .	Stone City.	11,250	136	Ohio.	Marbleh'd (w'e).	12,600	150
Kan. .	Marion.	12,364	168	Wis. . .	Sturgeon Bay (blue).	21,500	174
Ky. . .	Warren Co.	6,795	. . . .	" . .	Waukesha	8,880	. . . .
" . . .	Bardst'n (da'k).	16,250	168	Pa. . . .	Avondale (gray)	18,000	. . . .
Minn. .	Winona.	16,250	160	" . . .	" (light)	12,112	. . . .
"	Stillwater.	15,000	172	" . . .	Conshohocken.	15,000	. . . .
"	Redwing.	23,000	162				

CHEMICAL COMPOSITION, WEIGHT, AND CRUSHING STRENGTH OF VARIOUS MARBLES.

State.	Location.	Carbonate of Lime.	Iron.	Carbonate of Magnesia.	Insoluble.	W'ght per Square Foot.	Crushing Str'ng'h per Square Inch.
Cal. . .	Inyo.	78.36	.017	21.79	2.6	. . . . . .	29,000
" . .	Colton.	92.9	. . . . . .	4.5	2.6	. . . . . .	9,350
" . .	Beulah.	98 00	.04	.05	.06	. . . . . .	. . . . . .
Ga. . . .	Cherokee	98.96	. . . . . .	.13	.61	171	10,970
" . . .	Creole.	98.	. . . . . .	.26	.50	172	12,078
" . . .	Etowah.	97.32	.26	1.60	.62	169	10,642
Ill. . . .	Mill Creek.	. . . . . .	. . . . . .	. . . . . .	. . . . . .	172	9,687
Md. . .	Cockysville.	. . . . . .	. . . . . .	. . . . . .	. . . . . .	178	23,500
Mass. .	Lee.	69.64	. . . . . .	27.98	1.00	. . . . . .	18,047
" .	Westfield.	79.68	. . . . . .	19.68	.20	. . . . . .	21,820
" .	Great Barrington. . . .	98.34	.14	.50	.38	. . . . . .	10,910
" .	Hastings.	52.82	. . . . . .	45.78	. . . . . .	. . . . . .	18,941
N. Y. .	South Dover	77.29	. . . . . .	20.25	.90	. . . . . .	18,836
"	East Chester	. . . . . .	. . . . . .	. . . . . .	. . . . . .	179	13,500
"	Pleasantville.	54.12	. . . . . .	45.04	.10	. . . . . .	12,692
"	Sing Sing.	53.24	. . . . . .	45.89	. . . . . .	. . . . . .	. . . . . .
Pa. . . .	Annville.	95.10	.23	3.96	1.07	. . . . . .	12,210
" . . .	Montgomery (blue). .	98.15	.54	.50	.77	180	18,000
Tenn. .	East Tennessee.	98.78	.26	.67	.08	. . . . . .	15,750
Vt. . . .	Proctor.	98.37	.03	.77	.63	. . . . . .	. . . . . .
" . . .	Rutland (white). . . .	97.73	.59	. . . . . .	1.68	166	10,746
" . . .	Rutland (green)	85.45	14.55	. . . . . .	. . . . . .	. . . . . .	. . . . . .
" . . .	Dorset.	. . . . . .	. . . . . .	. . . . . .	. . . . . .	165	7,612
Va. . . .	Montgomery	. . . . . .	. . . . . .	. . . . . .	. . . . . .	. . . . . .	8,950
Wis. . .	North Bay.	. . . . . .	. . . . . .	. . . . . .	. . . . . .	175	20,025

CRUSHING STRENGTH OF STONES, ETC.

Material.	Crushing Strength in Pounds per Sq. Inch. From	To
Lee, Mass., marble	20,504	22,900
Potomac red sandstone	16,625	22,102
Coshohocken, Pa., limestone	14,090	16,340
Hummelstown, Pa., sandstone	12,810	13,610
Montgomery Co., Pa., blue marble	9,590	13,700
Philadelphia pressed bricks	7,210	9,050
Indiana limestone	7,190	10,620
Philadelphia hard bricks	5,540	20,830
Ohio sandstone	3,940	16,280
Brick masonry in cement mortar	1,600	2,685
Brick masonry in lime mortar	799	1,914

SPECIFIC GRAVITY, WEIGHT, AND CRUSHING STRENGTH OF BRICK.

Name.	Specific Gravity.	Weight per Cubic Foot in Pounds.	Crushing Strength per Square Inch in Pounds.
Best pressed	2.4	150	5,000 to 14,973
Common hard	1.6 to 2.0	125	5,000 to 8,000
Soft	1.4	100	450 to 600

The New York Building Code gives the working strength of brickwork as follows:

	Pounds per Sq. Inch.
Brickwork in Portland-cement mortar: cement, 1; sand, 3	208
Brickwork in lime and cement mortar: cement, 1; lime, 1; sand, 6	160
Brickwork in lime mortar: lime, 1; sand, 4	111

WEIGHT OF BRICKWORK.

Placing the weight of brickwork at 112 lbs. per cubic foot, the weights per superficial foot for different walls are as follows:

For 9-inch wall	84 lbs.
For 13-inch wall	121 "
For 18-inch wall	168 "
For 22-inch wall	205 "
For 26-inch wall	243 "

CHEMICAL ANALYSIS OF VARIOUS SANDSTONES.

State.	Location.	Quarry.	Silica.	Oxide of Alumina.	Oxide of Magnesia.	Oxide of Sodium.	Carbon.	Oxide of Potassium.	Ferric Oxide	Oxide of Calcium.	Water and Loss.
Arizona.	Flagstaff.	Arizona Sandstone Co.	79.19	1.30	.23		5.77		2.45	7.76	.32
California.	Colusa.	Colusa Stone Co.	85.99	4.82	.76				4.49	1.87	.69
Connecticut.	Cromwell.	N. E. Brown Stone Co.	70.84	13.15		5.43	1.01	3.30	2.48	3.09	
"	Portland.	(Brown stone).	69.94	13.15					2.48	3.09	1.01
Indiana.	Riverside.	Guyer & Burchby.	93.16	1.60					2.64	.13	
"	St. Anthony.	J. B. Lynn.	88.41	.63			.10		8.40	.13	
"	Williamsport.	Williamsport Stone Co.	98.57	.05			.02		.65	.02	
Kansas.	Valley Falls.	J. M'Ginty.	94.35	2.35	1.01					1.14	
Kentucky.	Rock Castle.	Rock Castle Blue Stone Co.	91.07	4.92						1.18	2.36
Maryland.	Frostburg.	B. Randolph.	99.40	.47					.27	.10	
Michigan.	Lake Superior	Portage Entry Quarries Co.	85.60	8.32	.18	.53		2.91	.28	.55	.99
Massachusetts.	E. L'gmeadow	Norcross Bros.	81.38	9.44	.28				3.54	.76	
"	Worcester.		88.89	5.95					1.79	.27	1.83
Minnesota.	Kettle River	Minnesota Sandstone Co.	98.69	1.06	.01	.17				.42	
"	Fon du Lac		78.24	10.88					3.83	.95	
New Jersey	Avondale.	Passaic Quarry Co	82.05	5.27	.76	.20	4.40	.60	2.71	3.35	.71
New York	Oxford.	F. G. Clark Co	77.56	10.65	1.22	.90		2.15	4.59	.34	1.93
" "	Stoneco.	Hudson River Stone Co.	63.24	19.52							
" "	Rock Glenn.	Warsaw Blue Stone Co.	76.50	14.75	1.29		2.72		6.35	3.80	2.00
N. Carolina	Carthage.	A. H. M'Neal.	79.63	7.16	2.63			4.66	4.16	.92	
Ohio.	Amherst.		97.00		.97				2.30	1.86	.20
"	Berea.		96.00						1.68	1.15	.21
"	Massilon.	Chippewa Stone Co.	97.36	2.28	.08					.05	
"	Lancaster.	F. C. Neeb.	97.76	.73					.51	.12	.51
"	Euclid.		95.00	2.50					1.00		
"	Grafton.		87.66	1.72					3.52	.17	2.03
Oregon.	Chitwood.	Victor Sandstone Co.	72.45	12.60					10.80	4.10	1.50
"	Forest Grove.	Forest Grove Stone Co.	55.21	17.87					14.75	2.19	
Pennsylvania.	Hummelsto'n	Hum'town Bluestone Co. (blue)	90.34	4.35	.17	.19		1.30	1.09	.95	.61
"	"	Do. do. do. (brown)	88.96	4.74	.44	.24		1.31	2.19	.86	.87
"	Swarta.	Swarta Stone Co.	91.52	3.80	.22			1.20	2.02	.50	1.
"	Laurel Run.	Laurel Run Stone Co.	94.00		1.00				1.98	1.10	.92
"	White Haven	Pennsylvania Quarry Co.	90.36	2.17					1.15	2.00	1.
"	Lathrop.	Frank Carlucci	91.40	6.64					.16		3.28
Utah.	Jennings Spur	Kyune Gray Stone Co.	83.64	.46	.70				1.96	8.50	.22
Wisconsin.	Ashland.	Prentice Stone Co.	91.40	3.53		.14		2.36	2.00	.25	.05

CHEMICAL ANALYSIS OF VARIOUS LIMESTONES.

State.	Location.	Quarry.	Carbonate of Calcium.	Carbonate of Magnesia.	Ox. Iron & Alumina.	Silica.	Oxide of Calcium.
Ill. . . .	Quincy.	F. W. Menke Stone Co. .	92.77	6.75	.27	15.90	. . . .
" . . .	Lemont.	. . . .	45.80	. . . .	9.30	15.90	. . . .
" . . .	Joliet.	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
Ind. . .	Bedford	Bedford Quar. Co.	98.20	.39	.39	.63	. . . .
" . .	"	" " " (blue)	97.26	.37	.49	1.69	. . . .
" . .	Spencer.	. . . .	96.80	.11	.91	.70	. . . .
" . .	Clear Creek. . . .	Acme Stone Co.	97.37	.78	.13	.84	.10
" . .	Peru.	J. N. Hurtz	52.90	38.94	1.25	4.05	. . . .
Iowa. .	Monmouth. . . .	L. B. Stewart Co.	57.54	41.51	. . . .	.42	. . . .
Kan. .	Marion.	I. Kuhn & Co.	91.50	1.62	1.24	5.51	. . . .
Ky. . .	Warren Co. . . .	Caden Stone Co.	54.80	. . . .	.22	.76	. . . .
" . . .	Bowling Green	. . . .	95.31	1.12	.39	1.42	. . . .
Mich. .	Trenton	Sibly Quarry Co	98.53	.53	.06	.60	. . . .
Minn. .	Kasota.	. . . .	49.16	37.53	1.09	13.06	. . . .
"	Stillwater.	. . . .	50.22	37.39	.78	8.74	. . . .
"	Frontenac.	. . . .	54.78	42.53	.67	2.73	. . . .
Mo. . .	Carthage.	Myers Stone Co	98.57	.65	.21	.69	. . . .
N. Y. .	Cobbleskill	Cobbleskill Quarry Co. .	41.90	1.65	.97	4.31	51.05
"	Amsterdam. . .	. . . .	42.64	. . . .	1.08	3.82	52.46
Ohio. .	Cold Springs. . .	Casparis Stone Co	54.05	44.94	.23	.49	. . . .
" . .	Tiffin.	. . . .	. . . .	40.36	.10	1.61	57.44
" . .	Dayton.	. . . .	92.40	1.10	.58	1.70	. . . .
" . .	Springfield. . . .	. . . .	54.70	44.93	.20	.10	. . . .
Pa. . . .	Youngstown. . .	Carbon Limestone Co. .	96.43	.40	1.60	1.50	. . . .
" . . .	Norristown. . . .	Wm. Rambo.	53.49	45.76	. . . .	.70	. . . .
R. I . .	Lime Rock. . . .	Herbert Harris	88.23	8.79	.32	2.74	. . . .
W. Va	Marlow.	G. C. Ditto.	. . . .	.98	.26	.18	98.44
Wis. . .	Hamilton.	Hamilton Stone Co.	54.25	44.48	.10	.67	. . . .

PRODUCTION AND USE OF MARBLE QUARRIED IN THE U. S. DURING 1901.

State.	Rough	Building.	Orna-m'tal.	Cemetery.	Interior.	Other.	Total.
Alaska.	$4,500	. . . .	. . . . . .	. . . .	. . . .	. . . . . .	$4,500
Arizona.	300	. . . .	. . . . . .	. . . .	. . . .	. . . . . .	300
Arkansas.	200	. . . .	$100	. . . .	. . . .	. . . . . .	300
California.	3,280	$1,550	1,812	. . . .	. . . .	. . . . . .	6,642
Georgia.	268,761	241,683	16,500	$207,305	$166,305	$36,000	936,549
Maryland.	8,100	45,000	. . . . . .	15,000	. . . .	. . . . . .	68,100
Massachusetts. . .	63,556	26,220	3,700	9,560	15,051	8,459	126,546
Missouri.	. . . . . .	. . . .	. . . . . .	2,100	. . . .	. . . . . .	2,100
Montana.	. . . . . .	. . . .	. . . . . .	1,500	. . . .	. . . . . .	1,500
New Mexico. . . .	4,200	3,000	300	3,100	. . . .	. . . . . .	10,600
New York.	2,367	132,943	4,900	204,289	28,000	6,660	379,159
Oregon	. . . . . .	. . . .	. . . . . .	500	. . . .	. . . . . .	500
Pennsylvania. . .	18,078	111,069	. . . . . .	25,060	400	2,940	157,547
Tennessee.	162,513	13,000	. . . . . .	14,000	305,124	. . . . . .	494,637
Utah.	320	. . . .	. . . . . .	. . . .	. . . .	. . . . . .	320
Vermont.	53,892	659,200	94,450	1,452,434	493,607	. . . . . .	2,753,583
Washington. . . .	1,600	2,358	4,814	14,044	. . . .	. . . . . .	22,816
Totals.	591,667	1,236,023	126,576	1,948,892	1,008,482	54,059	4,965,699

CHEMICAL ANALYSIS OF GRANITES FROM VARIOUS QUARRIES.

State.	Location.	Quarry.	Silica.	Oxide of Alumina.	Oxide of Magnesia.	Oxide of Sodium	Oxide of Potassium.	Oxide of Iron.	Oxide of Calcium.
California	Exeter	Rocky Point Granite Works	75.35	13.69	.06	1.14	2.85	3.94	2.97
Connecticut	Waterford	Hurricane Isle Granite Co.	68.11	14.28	.68	6.57	5.46	....	1.86
"	Meriden	(Trap rock)	52.37	15.06	5.38	4.04	....	....	7.33
Delaware	Rockford	Brandywine G't Co. (gneiss)	67.98	16.14	.53	4.32	.45	....	5.89
Maine	Waldoboro	Booth Bros	73.48	15.26	.09	3.12	5.66	....	....
"	North Jay	Maine and N. H. Granite Co.	71.54	14.24	....	3.39	4.73	....	.98
"	Blue Hill	Chase Granite Co.	73.02	16.22	....	3.60	3.42	....	.94
"	" "	Blue Hill Granite Co.	74.64	14.90	....	.41	6.88	....	.39
Maryland	Point Deposit	M'Clenahan Bros.	73.69	12.89	.49	2.81	1.48	....	3.73
Minnesota	East St. Cloud		65.12	16.96	....	5.25	....	4.69	4.77
Massachusetts	Cape Ann	Rockport Granite Co.	81.05	14.70	....	....	....	....	1.10
"	Milford	Shea Pink Granite Co.	76.95	11.15	....	5.60	5.03	....	....
"	"	Norcross Bros.	76.07	12.67	.10	3.37	4.71	....	.85
"	Monson	(Trap rock)	52.59	23.42	.28	....	....	....	9.05
"	"	Light granite	73.47	15.07	....	5.97	....	1.15	4.48
"	"	Dark granite	69.35	18.23	....	3.78	....	2	5.94
Nevada	Reno	Jno. Barret	58.67	14.89	1.79	7.68	2.69	....	5.68
N. Hampshire	Red Stone	N. H. Granite Co. (red)	71.44	14.72	.96	7.66	.89	....	....
"	" "	" " " (green)	70.42	14.64	1.20	7.80	.71	....	....
"	Troy	Troy Granite Co.	73.15	17.04	.30	2.05	5.74	....	.81
"	Mason	Mason Granite Co.	72.47	16.17	.14	3.43	4.83	....	1.65
New Jersey	Little Falls	Francesco Bros. (trap)	50.81	13.25	6.97	.76	1.71	....	10.96
New York	Stormy P't.	Daniel Donovan	63.19	10.50	1.43	1.91	4.01	....	6.12
Pennsylvania	Birdsboro	John T. Dyer Co.	46.87	13.36	4.35	4.64	2.01	....	14.70
Vermont	Barre	Wells, Lamson & Co.	69.56	15.38	....	5.38	4.31	....	1.76
Virginia	Petersburg	Petersburg Granite Co.	64.12	20.91	.66	4.57	4.82	2.96	1.98
"	Richmond	P. Copeland	60.65	16.87	2.39	2.18	3.80	....	1.91
Wisconsin	Waushara Co.	Milwaukee Monument Co.	76.62	13.02	.05	2.24	6.38	....	.51
"	Berlin	E. J. Nelson	73.65	11.19	.51	3.74	1.86	....	2.78

LOCATION OF QUARRY AND BUILDING IN WHICH VARIOU
GRANITES HAVE BEEN USED.

Location of Quarry.	Building Used in.	Color.
Concord, N. H.	National Library, Washington, D.C.	Light gray
" "	N. H. State House.	Light gray
Hallowell, Maine.	State Capitol, Albany, N. Y.	Light gray
Quincy, Mass.	King's Chapel, Boston.	Dark gray
" "	U. S. Court-house, Boston.	Dark gray
" "	Masonic Temple.	Dark gray
" "	Stairway, pilasters, etc., City Hall, Philadelphia, Pa.	Dark gray
Dedham, Mass.	Trinity Church, Boston.	Pink
Vinalhaven, Mass.	Masonic Temple, Philadelphia.	Gray
Red Beach, Maine.	....	Red & pink
Jonesboro, Maine.	....	Red & pink
Dix Island, Maine.	New York Post-office.	
Cape Ann, Mass.	Post-office, Boston.	
Milford, Mass.	City Hall, New York.	
North Conway, N. H.	Union Depot, Portland, Me.	Red & greer
Lynn, Conn.	Chaney Memorial Church, Newport, R. I.	Deep red
Grindstone, N. Y.	Columns, State Capitol, Albany, N. Y.	
Westerly, R. I.	....	Light gray and pink
Richmond, Va.	State, War, and Navy Department buildings, Washington, D. C.	Gray
Georgia.	....	Light and dark gray
Graniteville, Mo.	....	Red mottl'c with gray
St. Cloud, Minn.	....	Gray & rec
Gunnison, Colo.	Colorado State House.	Blue gray
Little Cottonwood Canyon	Utah Mormon Temple, Salt Lake City.	

RESISTANCE OF PAVEMENTS TO WEAR.

EXPERT TESTS MADE BY JOHN M. GREGORY FOR G. W. BARTHOLOMEW OF THE PORTLAND CEMENT CO., DENVER, OF THE RESISTANCE TO WEAR OF THE VARIOUS PAVING STONES AND CEMENTS USED.

Several good samples of each kind were made with one-inch square sections. They were pressed on a true-faced grindstone, running 333 feet per minute, by a 20-pound weight, and the time necessary to grind $\frac{5}{16}$ of an inch from the one-inch square surface of each determined.

It was found that mortar made of one-fourth Portland cement and three-fourths sand resisted the wear of the stone six times as long as the hardest marble. The relative hardness

LOCATION OF QUARRY AND BUILDING IN WHICH VARIOUS SANDSTONES HAVE BEEN USED.

State.	Location of Quarry.	Building Used in.	Color of Stone.
Conn..	Portland.	Technology Building, Boston. ...	Brown
"	"	Astor Library, New York City. ..	Brown
"	"	Music Hall, Buffalo, N. Y.	Brown
"	"	Union League Club B'ld'g. Phila.	Brown
"	"	Savings Bank of Baltimore.	Brown
"	"	Residence of W. H. Vanderbilt, New York.	Brown
Colo. .	Fort Collins. . .	Grace Methodist Church, Denver	Dark red
"	"	Union Pacific Depot, Cheyenne, Wyoming.	Dark red
Mass. .	Longmeadow. .	Union League Club, Chicago.	Red
"	" .	Trimmings Trinity C'ch, Boston..	Red
Mich. .	Portage Entry (Lake Superior)	New Waldorf-Astoria Hotel, N.Y.	Red
"	Do. do.	U. S. Post-office, Rockford, Ill ...	Red
"	Marquette	Court House, Muskegon, Mich ...	Brown
Minn..	Kettle River . .	Library Bldg., Univ. of Illinois. ..	Cream
"	Fond du Lac. .	Presbyterian Church, Minneapolis, Minn.	Reddish brown
N. Y. .	Potsdam.	Parliament B'ld'gs, Ottawa, Ont.	Red
"	"	Columbia College, New York City.	Red
"	Medina.	U. S. Government Building, Rochester, N. Y.	Pink
Ohio. .	Amherst.	Palmer House, Chicago.	Buff
"	"	State Capitol, Lansing, Mich	Buff
"	"	State Historical Library, Minneapolis, Minn.	Buff
"	"	Wood Co., Ohio, Court House. ...	Gray
"	Berea.	U. S. Post-office, Minneapolis, Minn.	Blue-gray
Pa. ...	Hummelstown	U. S. Marine Barracks, League Island.	Brown

of others is given by the minutes it took to grind $\frac{5}{16}$ of an inch from the face of each, as follows:

	Minutes.
Portland Cement, $\frac{1}{4}$ Cement, $\frac{3}{4}$ sand	100.
Louisville cement, pure..................	1.4
Berea Paving Stone.....................	2.4
Excross Roads Paving Stone............	2.6
Iberia Paving Stone....................	2.
Slag Cement, pure......................	5.
Hard Marble..........................	16.
English Portland Cement..............	25.

Extensive trials in Boston and in Germany of relative resistance to wear of stone and cement confirm above figures.

SAFE LOADS IN TONS OF 2000 POUNDS FOR SQUARE WOODEN PILLARS.

Unsupported Length of Column in Feet.	Size of Pillar in Inches.						
	6×6	8×8	9×9	10×10	12×12	14×14	16×16
	White Pine or Spruce.						
6	12.80	....	....	....	....	....	....
8	11.70	22.7	29.6	....	....	....	....
10	10.60	21.3	28.0	35.5	....	....	....
12	9.54	19.8	26.3	33.7	51.1	....	....
14	8.46	18.4	24.7	31.9	49.0	69.6	....
16	7.38	17.0	23.1	30.1	46.8	67.0	91.0
18	....	15.5	21.5	28.3	44.7	64.5	88.0
20	....	14.1	19.8	26.5	42.5	62.0	85.2
22	....	....	18.2	24.7	40.3	59.5	82.3
24	....	....	....	22.9	38.2	57.0	79.4
	White Oak.						
6	14.80	....	....	....	....	....	....
8	13.50	26.2	34.0	....	....	....	....
10	12.20	24.6	32.4	41.0	....	....	....
12	11.00	22.7	30.4	39.1	59.1	....	....
14	9.73	21.1	28.4	36.7	56.9	80.4	....
16	8.64	19.5	26.5	34.6	54.0	77.8	105.0
18	....	17.8	24.7	32.4	51.1	74.5	102.0
20	....	16.3	22.7	30.5	49.1	71.3	98.5
22	....	....	21.1	28.2	46.1	68.3	94.7
24	....	....	....	26.4	43.9	65.5	90.9
	Yellow Pine (Southern).						
6	18.0	....	....	....	....	....	....
8	16.4	32.0	41.6	....	....	....	....
10	14.9	29.9	39.4	50.0	....	....	....
12	13.3	27.8	36.9	47.6	72.0	....	....
14	11.9	25.8	34.7	44.7	69.1	98.0	132.0
16	10.4	23.7	32.3	42.3	65.5	94.6	128.0
18	....	21.8	30.0	39.5	62.6	90.7	124.0
20	....	19.8	27.8	37.0	59.8	86.9	120.0
22	....	....	25.7	34.6	56.2	83.6	115.0
24	....	....	....	32.2	53.3	80.0	111.0

SAFE LOADS UNIFORMLY DISTRIBUTED FOR RECTANGULAR SPRUCE OR WHITE-PINE BEAMS ONE INCH THICK.

The following table has been calculated for extreme fibre stresses of 750 pounds per square inch corresponding to the following values for moduli of rupture recommended by Prof. Lanza, viz.:

Spruce and white pine.......................... 3000 lbs.
Oak.. 4000 "
Yellow pine.................................... 5000 "

For oak increase values in table by $\frac{1}{3}$. For yellow pine increase values in table by $\frac{2}{3}$.

The safe load for any other values per square inch is found by increasing or decreasing the loads given in the table in the same proportion as the increased or decreased fibre stress.

Span in Feet.	Depth of Beam.										
	6 Ins.	7 Ins.	8 Ins.	9 Ins.	10 Ins.	11 Ins.	12 Ins.	13 Ins.	14 Ins.	15 Ins.	16 Ins.
5	600	820	1070	1350	1670	2020	2400	2820	3270	3750	4270
6	500	680	890	1120	1390	1680	2000	2350	2730	3120	3560
7	430	580	760	960	1190	1440	1710	2010	2330	2680	3050
8	380	510	670	840	1040	1260	1500	1760	2040	2340	2670
9	330	460	590	750	930	1120	1330	1560	1810	2080	2370
10	300	410	530	670	830	1010	1200	1410	1630	1880	2130
11	270	370	490	610	760	920	1090	1280	1490	1710	1940
12	250	340	440	560	690	840	1000	1180	1360	1560	1780
13	230	310	410	520	640	780	930	1080	1260	1440	1640
14	210	290	380	480	590	720	860	1010	1170	1340	1530
15	200	270	360	450	560	670	800	940	1090	1250	1420
16	190	260	330	420	520	630	750	880	1020	1180	1330
17	180	240	310	400	490	590	710	830	960	1100	1260
18	170	230	290	370	460	560	670	780	910	1040	1190
19	160	210	280	360	440	530	630	740	860	990	1130
20	150	200	270	340	420	510	600	710	820	940	1070
21	140	190	260	320	390	480	570	670	780	890	1020
22	140	190	240	310	380	460	540	640	740	850	970
23	130	180	230	290	360	440	520	610	710	810	920
24	130	170	220	280	350	420	500	590	680	780	890
25	120	160	210	270	330	410	480	560	660	750	860
26	110	160	210	260	320	390	460	540	630	720	820
27	110	150	200	250	310	370	440	520	610	690	790
28	110	140	190	240	300	360	430	500	580	670	760
29	110	140	180	230	290	350	410	490	560	640	740

To obtain the safe load for any thickness multiply values for 1 inch by thickness of beam.

To obtain the required thickness for any load divide by safe load for 1 inch.

STRENGTH, WEIGHT, ETC., OF VARIOUS WOODS.

Name.	Strength per Sq. In. in Lbs. Tensile.	Strength per Sq. In. in Lbs. Crushing in Direction of Grain.	Moduli of Elasticity.	Relative Hardn'ss Shell-bark Hickory being 1000.	Weight per Cubic Foot.	Specific Gravity.
Acacia-wood	....	....	....	....	46.5	.750
Alder-wood	....	6,150	....	....	50	.800
Apple-wood	....	....	....	700	49	.793
Ash (white)	17,000	8,600	....	775	40.77	.610
Ash (brown)	11,000	....	....	....	38.96	.623
Boxwood	18,000	10,000	....	....	62	.990
Birch	15,000	8,000	....	630	35.44	.567
Beech	11,500	9,000	....	660	40.42	.650
Butternut	9,000	6,000	....	440	23.50	.376
Cherry	....	....	....	550	44.70	.715
Chestnut	10,500	5,000	1,000,000	520	41.25	.660
Cork	....	....	....	....	15	.240
Cedar (white)	11,400	6,500	700,000	540	37.25	.596
Cedar (red)	9,000	6,000	....	....	35	.560
Cypress	5,000	6,000	900,000	....	27.60	.441
Dogwood	....	....	....	750	47.25	.750
Ebony	....	....	....	....	86.16	1.331
Elm	13,000	8,000	....	580	42	.671
Fir	10,000	7,000	1,200,000	....	32	.512
Gum	17,000	7,000	....	....	52.69	.843
Hazel	....	....	....	720	53.75	.860
Holly	....	....	....	....	47.50	.760
Hickory (pignut)	15,000	9,000	....	950	49.50	.792
Hickory (shell-bark)	18,000	10,000	....	1000	43.12	.690
Hemlock	8,740	5,400	900,000	....	23.00	.368
Hackmatack	....	....	....	....	37.00	.592
Juniper	....	....	....	....	35.37	.566
Lancewood	....	....	....	....	45	.720
Larch	9,500	....	....	....	34.55	.552
Lignum-vitæ	12,000	9,000	....	....	83.31	1.333
Logwood	....	....	....	....	57.06	.913
Locust	20,000	11,720	....	....	45.50	.728
Mahogany	12,000	6,000	....	....	55.75	.829
Maple (hard)	10,000	9,000	....	550	46.87	.750
Maple (white)	10,000	7,000	....	....	36	.576
Oak (white)	16,000	6,000	1,100,000	850	53.75	.860
Oak (red or black)	10,000	8,000	....	700	40.75	.652
Pear	9,800	....	....	....	47	.752
Plum	....	....	....	....	49.06	.785
Poplar	7,000	5,000	....	510	23.99	.383
Pine (white)	7,000	5,000	1,000,000	300	30	.480
Pine (Norway)	8,300	7,000	1,200,000	....	33.25	.532
Pine (yellow)	16,000	5,500	1,200,000	540	38.40	.612
Pine (yellow long-leaf)	20,000	9,000	1,700,000	....	43.62	.698
Pine (Oregon)	13,800	7,000	1,400,000	....	34	.544
Rosewood	....	....	....	....	45.50	.728
Redwood (Cal.)	8,000	2,500	7,00000	....	26.23	.419
Satinwood	....	....	....	....	55.31	.885
Spruce (white)	14,000	6,500	1,200,000	....	31.25	.500
Tamarack	....	....	....	....	23.93	.383
Walnut	10,000	8,000	....	650	41.93	.671
Willow	12,000	....	....	....	33.40	.535

ULTIMATE STRENGTH OF HOLLOW ROUND AND HOLLOW RECTANGULAR CAST-IRON COLUMNS.

Ultimate strength in pounds per square inch:

Round Columns.			Rectangular Columns.		
Square Bearing.	Pin and Square.	Pin Bearing.	Square Bearing.	Pin and Square.	Pin Bearing.
$\dfrac{80000}{1+\dfrac{(12l)^2}{800d^2}}$	$\dfrac{80000}{1+\dfrac{3(12l)^2}{1600d^2}}$	$\dfrac{80000}{1+\dfrac{(12l)^2}{400d^2}}$	$\dfrac{80000}{1+\dfrac{3(12l)^2}{3200d^2}}$	$\dfrac{80000}{1+\dfrac{9(12l)^2}{6400d^2}}$	$\dfrac{80000}{1+\dfrac{3(12l)^2}{1600d^2}}$

l = length of column in feet;
d = external diameter or least side of rectangle in inches.

$\dfrac{l}{d}$	Round Columns. Ultimate Strength in Pounds per Square Inch.			Rectangular Columns. Ultimate Strength in Pounds per Square Inch.		
	Square Bearing.	Pin and Square.	Pin Bearing.	Square Bearing.	Pin and Square.	Pin Bearing.
1.0	67800	62990	58820	70480	66520	62990
1.1	65690	60300	55730	68790	64260	60300
1.2	63530	57600	52690	67000	61940	57600
1.3	61340	54930	49740	65140	59600	54960
1.4	59140	52310	46900	63260	57270	52320
1.5	56940	49770	44200	61350	54960	49760
1.6	54760	47300	41630	59450	52680	47300
1.7	52620	44940	39210	57550	50460	44960
1.8	50530	42670	36930	55670	48300	42670
1.9	48490	40510	34790	53800	46230	40510
2.0	46510	38460	32790	51940	44200	38400
2.1	44600	36520	30920	50160	42260	36520
2.2	42750	34680	29180	48400	40400	34680
2.3	40980	32940	27540	46670	38630	32950
2.4	39280	31310	26030	44990	36930	31310
2.5	37650	29770	24620	43390	35310	29760
2.6	36090	28320	23300	41820	33770	28320
2.7	34600	26950	22070	40320	32310	26950
2.8	33180	25670	20930	38870	30920	25670
2.9	31820	24460	19860	37470	29600	24460
3.0	30530	23320	18870	36120	28340	23320
3.1	29310	22250	17940	34830	27150	22250
3.2	28140	21250	17070	33580	26030	21250
3.3	27030	20300	16260	32390	24960	20300
3.4	25970	19410	15500	31240	23940	19410

SAFE LOADS IN TONS OF 2000 LBS. FOR HOLLOW ROUND CAST-IRON COLUMNS.

Outside Diameter, Inches.	Thickness of Metal.	Length of Columns in Feet.									Sectional Area, Inches.	Weight, Lbs. of Col. per Ft. of L'gth.
		8	10	12	14	16	18	20	22	24		
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons		
6	½	26.2	23.0	20.1	17.5	15.2	13.2	11.5	.....	.....	8.6	26.95
6	¾	37.5	33.0	28.8	25.0	21.7	18.9	16.5	.....	.....	12.4	38.59
6	⅞	42.7	37.6	32.8	28.5	24.7	21.5	18.8	.....	.....	14.1	43.96
6	1	47.6	41.9	36.5	31.8	27.6	24.0	21.0	.....	.....	15.7	49.01
6	1⅛	52.2	46.0	40.1	34.8	30.2	26.3	23.0	.....	.....	17.2	53.76
7	¾	47.7	43.1	38.5	34.3	30.4	26.9	23.9	21.2	18.9	14.7	45.96
7	1	61.1	55.2	49.3	43.8	38.9	34.4	30.6	27.1	24.2	18.9	58.90
7	1⅛	67.2	60.8	54.3	48.3	42.8	37.9	33.7	29.9	26.7	20.8	64.77
8	¾	57.9	53.3	48.6	44.1	39.7	35.8	32.2	28.9	26.1	17.1	53.29
8	1	74.6	68.7	62.5	56.7	51.1	46.0	41.4	37.3	33.6	22.0	68.64
8	1¼	89.9	82.8	75.5	68.4	61.7	55.5	49.9	44.9	40.5	26.5	82.71
9	¾	68.1	63.6	58.9	54.2	49.6	45.2	41.2	37.5	34.1	19.4	60.65
9	1	88.0	82.3	76.2	70.0	64.1	58.4	53.2	48.4	44.1	25.1	78.40
9	1¼	106.6	99.6	92.2	84.8	77.6	70.8	64.4	58.7	53.4	30.4	94.94
9	1½	123.8	115.7	107.1	98.5	90.1	82.2	74.8	68.1	62.0	35.3	110.26
9	1¾	139.6	130.5	120.8	111.1	101.6	92.7	84.4	76.8	69.9	39.9	124.36
10	1	101.4	95.9	89.8	83.6	77.4	71.5	65.8	60.5	55.5	28.3	88.23
10	1¼	123.3	116.5	109.1	101.6	94.1	86.8	79.9	73.4	67.5	34.4	107.23
10	1½	143.7	135.8	127.3	118.5	109.7	101.2	93.2	85.6	78.7	40.1	124.99
10	1¾	162.7	153.8	144.1	134.1	124.2	114.6	105.5	97.0	89.1	45.4	141.65
11	1	114.8	109.4	103.5	97.3	91.0	84.8	80.2	73.1	67.7	31.4	98.03
11	1¼	139.9	133.3	126.1	118.6	110.9	103.3	97.8	89.4	82.5	38.3	119.46
11	1½	163.5	155.9	147.5	138.6	128.7	120.8	114.3	104.1	96.4	44.8	139.68
11	1¾	185.7	177.1	167.5	157.5	147.3	137.2	129.8	118.3	109.5	50.9	158.68
11	2	206.6	196.9	186.3	175.1	163.8	152.6	144.4	131.5	121.8	56.6	176.44
12	1	128.0	122.9	117.2	111.0	104.7	98.4	92.2	86.1	80.4	34.6	107.51
12	1¼	156.4	150.1	143.1	135.7	127.9	120.2	112.6	105.2	98.2	42.2	131.41
12	1½	183.3	175.9	167.7	159.0	149.9	140.9	132.0	123.3	115.1	49.5	154.10
12	1¾	208.7	200.4	191.0	181.1	170.7	160.4	150.3	140.5	131.1	56.4	175.53
12	2	232.7	223.4	213.0	201.9	190.4	178.9	167.6	156.6	146.1	62.8	195.75
13	1	141.2	136.3	130.7	124.7	118.5	112.1	105.8	99.5	93.5	37.7	117.53
13	1¼	172.8	166.8	160.0	152.7	145.0	137.2	12[illegible].4	121.8	114.4	46.1	143.86
13	1½	203.0	195.9	187.9	179.3	170.3	161.1	152.0	143.1	134.3	54.2	168.98
13	1¾	231.6	223.6	214.5	204.7	194.4	183.9	173.5	163.3	153.3	61.9	192.88
13	2	258.9	249.9	239.7	228.7	217.3	205.5	193.9	182.5	171.3	69.1	215.56
14	1	154.3	149.6	144.3	138.5	132.3	125.9	119.5	113.1	106.8	40.8	127.60
14	1¼	189.2	183.4	176.9	169.7	162.2	154.4	146.5	138.6	131.0	50.1	156.31
14	1½	222.6	215.8	208.1	199.7	190.8	181.7	172.3	163.1	154.1	58.9	183.67
14	1¾	254.4	246.7	237.9	228.3	218.1	207.6	197.0	186.5	176.2	67.4	210.00
14	2	284.8	276.2	266.4	255.6	244.2	232.4	220.6	208.8	197.2	75.4	235.12
15	1	167.4	162.9	157.8	152.1	146.0	139.7	133.3	126.8	120.4	44.0	137.28
15	1¼	205.5	200.0	193.7	186.7	179.3	171.5	163.6	155.7	147.9	54.0	168.48
15	1½	242.1	235.7	228.2	220.0	211.2	202.1	192.8	183.5	174.2	63.6	198.74
15	1¾	277.2	269.8	261.3	251.9	241.9	231.4	220.7	210.1	199.5	72.9	227.45
15	2	310.8	302.5	293.0	282.5	271.2	259.5	247.5	235.5	223.6	81.7	254.90

If all cast-iron or other hollow columns are filled with concrete after being set it adds to their strength and affords protection from rust and fire.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	24″ I.	Add for Every Lb. Increase in Weight.	20″ I.		Add for Every Lb. Increase in Weight.	18″ I.	Add for Every Lb. Increase in Weight.	15″ I.			Add for Every Lb. Increase in Weight.
	80 Lbs.		80 Lbs.	65 Lbs.		55 Lbs.		80 Lbs.	60 Lbs.	42 Lbs.	
12	77.33	.53	65.18	51.98	.44	39.29	.39	47.14	36.09	26.18	.33
13	71.38	.48	60.16	47.98	.40	36.27	.36	43.51	33.31	24.17	.30
14	66.28	.45	55.87	44.56	.37	33.68	.34	40.40	30.93	22.44	.28
15	61.86	.42	52.14	41.59	.35	31.43	.31	37.71	28.87	20.94	.26
16	58.00	.39	48.88	38.99	.33	29.47	.29	35.35	27.07	19.63	.24
17	54.58	.37	46.01	36.69	.31	27.74	.28	33.27	25.47	18.48	.23
18	51.56	.35	43.45	34.66	.29	26.19	.26	31.42	24.06	17.45	.22
19	48.84	.33	41.17	32.83	.28	24.82	.25	29.77	22.79	16.53	.21
20	46.40	.32	39.11	31.19	.26	23.58	.24	28.28	21.65	15.71	.20
21	44.19	.30	37.24	29.70	.25	22.45	.22	26.94	20.62	14.96	.19
22	42.18	.29	35.55	28.35	.24	21.43	.21	25.71	19.68	14.28	.18
23	40.35	.27	34.01	27.12	.23	20.50	.20	24.59	18.83	13.66	.17
24	38.67	.26	32.59	25.99	.22	19.65	.20	23.57	18.04	03.19	.16
25	37.12	.25	31.29	24.95	.21	18.86	.19	22.63	17.32	12.57	.16
26	35.69	.24	30.08	23.99	.20	18.14	.18	21.76	16.66	12.08	.15
27	34.37	.23	28.97	23.10	.19	17.46	.17	20.95	16.04	11.64	.14
28	33.14	.23	27.93	22.28	.19	16.84	.17	20.20	15.47	11.22	.14
29	32.00	.22	26.97	21.51	.18	16.26	.16	19.51	14.93	10.83	.13
30	30.93	.21	26.07	20.79	.17	15.72	.16	18.86	14.43	10.47	.13
31	29.94	.20	25.23	20.12	.17	15.21	.15	18.25	13.97	10.13	.13
32	29.00	.20	24.44	19.49	.16	14.73	.15	17.68	13.53	9.82	.12
33	28.12	.19	23.70	18.90	.16	14.29	.14	17.14	13.12	9.52	.12
34	27.29	.19	23.00	18.35	.15	13.87	.14	16.64	12.74	9.24	.11
35	26.51	.18	22.35	17.82	.15	13.47	.13	16.16	12.37	8.98	.11
36	25.78	.18	21.73	17.33	.15	13.10	.13	15.71	12.03	8.73	.11

Safe loads given include weight of beam. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	12″ I.		Add for Every Lb. Increase in Weight.	10″ I.	Add for Every Lb. Increase in Weight.	9″ I.	Add for Every Lb. Increase in Weight.	Distance between Supports in Feet.	8″ I.	Add for Every Lb. Increase in Weight.
	40 Lbs.	31.5 Lbs.		25 Lbs.		21 Lbs.			18 Lbs.	
12	19.92	15.99	.26	10.85	.22	8.39	.20	5	15.17	.42
13	18.39	14.76	.24	10.02	.20	7.74	.18	6	12.64	.35
14	17.08	13.70	.23	9.30	.19	7.19	.17	7	10.84	.30
15	15.94	12.79	.21	8.68	.17	6.71	.16	8	9.48	.26
16	14.94	11.99	.20	8.14	.16	6.29	.15	9	8.43	.23
17	14.06	11.29	.19	7.66	.15	5.92	.14	10	7.59	.21
18	13.28	10.66	.18	7.24	.14	5.59	.13	11	6.90	.19
19	12.58	10.10	.17	6.86	.14	5.30	.12	12	6.32	.18
20	11.95	9.59	.16	6.51	.13	5.03	.12	13	5.83	.16
21	11.3[illegible]	9.14	.15	6.20	.12	4.79	.11	14	5.42	.15
22	10.87	8.72	.14	5.92	.12	4.58	.11	15	5.06	.14
23	10.39	8.34	.14	5.66	.11	4.38	.10	16	4.74	.13
24	9.96	7.99	.13	5.43	.11	4.19	.10	17	4.46	.12
25	9.56	7.67	.13	5.21	.10	4.03	.09	18	4.21	.12
26	9.19	7.38	.12	5.01	.10	3.87	.09	19	3.99	.11
27	8.85	7.11	.12	4.82	.10	3.73	.09	20	3.79	.11
28	8.54	6.85	.11	4.65	.09	3.59	.08	21	3.61	.10
29	8.24	6.62	.11	4.49	.09	3.47	.08	....	......	....
30	7.97	6.40	.11	4.34	.09	3.36	.08	....	......	....

Safe loads given include weight of beam. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	7″ I. 15 lbs.	Add for Every Lb. Increase in Weight.	6″ I. 12.25 lbs.	Add for Every Lb. Increase in Weight.	5″ I. 9.75 lbs.	Add for Every Lb. Increase in Weight.	4″ I. 7.5 lbs.	Add for Every Lb. Increase in Weight.	3″ I. 5.5 lbs.	Add for Every Lb. Increase in Weight.
5	11.04	.36	7.75	.31	5.16	.26	3.18	.21	1.76	.16
6	9.20	.30	6.46	.26	4.30	.22	2.65	.18	1.47	.13
7	7.89	.26	5.54	.22	3.69	.19	2.27	.15	1.26	.11
8	6.90	.23	4.84	.19	3.23	.16	1.99	.13	1.10	.10
9	6.13	.20	4.31	.17	2.87	.14	1.77	.12	0.98	.09
10	5.52	.13	3.88	.16	2.53	.13	1.59	.11	0.88	.08
11	5.02	.16	3.52	.14	2.35	.12	1.45	.10	0.80	.07
12	4.60	.15	3.23	.13	2.15	.11	1.33	.09	0.73	.07
13	4.25	.14	2.98	.12	1.98	.10	1.22	.08	0.68	.06
14	3.94	.13	2.77	.11	1.84	.09	1.14	.08	0.63	.06
15	3.63	.12	2.58	.10	1.72	.09	1.06	.07	0.59	.05
16	3.45	.11	2.42	.10	1.61	.08	0.99	.07	0.55	.05
17	3.25	.11	2.28	.09	1.52	.08	0.94	.06	0.52	.05
18	3.07	.10	2.15	.09	1.43	.07	0.88	.06	0.49	.04
19	2.91	.09	2.04	.08	1.36	.07	0.84	.06	0.46	.04
20	2.76	.09	1.94	.08	1.29	.07	0.80	.05	0.44	.04
21	2.63	.09	1.85	.07	1.23	.06	0.76	.05	0.42	.04

Safe loads given include weight of beam. Maximum fibre stress. 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL CHANNELS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	15″ ⊏ 33 lbs.	Add for Every Lb. Increase in Weight.	12″ ⊏ 20.5 lbs.	Add for Every Lb. Increase in Weight.	10″ ⊏ 15 lbs.	Add for Every Lb. Increase in Weight.	9″ ⊏ 13.25 lbs.	Add for Every Lb. Increase in Weight.
10	22.23	.39	11.39	.32	7.14	.26	5.61	.24
11	20.20	.35	10.35	.29	6.49	.24	5.10	.21
12	18.52	.33	9.49	.26	5.95	.22	4.68	.20
13	17.10	.30	8.76	.24	5.49	.20	4.32	.18
14	15.87	.28	8.14	.23	5.10	.19	4.01	.17
15	14.82	.26	7.59	.21	4.76	.17	3.74	.16
16	13.89	.24	7.12	.20	4.46	.16	3.51	.15
17	13.07	.23	6.70	.18	4.20	.15	3.30	.14
18	12.35	.22	6.33	.18	3.96	.14	3.12	.13
19	11.70	.21	5.99	.17	3.76	.14	2.95	.12
20	11.11	.20	5.70	.16	3.57	.13	2.81	.12
21	10.58	.19	5.42	.15	3.40	.12	2.67	.11
22	10.10	.18	5.18	.14	3.24	.12	2.55	.11
23	9.66	.17	4.95	.14	3.10	.11	2.44	.10
24	9.26	.16	4.75	.13	2.97	.11	2.34	.10
25	8.89	.16	4.56	.13	2.85	.10	2.24	.09
26	8.55	.15	4.38	.12	2.74	.10	2.16	.09
27	8.23	.14	4.22	.12	2.64	.10	2.08	.09
28	7.94	.14	4.07	.11	2.55	.09	2.00	.08
29	7.66	.13	3.93	.11	2.46	.09	1.93	.08
30	7.41	.13	3.80	.11	2.38	:09	1.87	.08

Safe loads given include weight of channel. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL CHANNELS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	8″ ⊏ 11.25 Lbs.	Add for Every Lb. Increase in Weight.	7″ ⊏ 9.75 Lbs.	Add for Every Lb. Increase in Weight.	6″ ⊏ 8 Lbs.	Add for Every Lb. Increase in Weight.	5″ ⊏ 6.5 Lbs.	Add for Every Lb. Increase in Weight.	4″ ⊏ 5.25 Lbs.	Add for Every Lb. Increase in Weight.	3″ ⊏ 4 Lbs.	Add for Every Lb. Increase in Weight.
5	8.61	.42	6.68	.36	4.62	.31	3.16	.26	2.02	.21	1.16	.16
6	7.18	.35	5.57	.30	3.85	.26	2.63	.22	1.68	.18	.97	.13
7	6.15	.30	4.77	.26	3.30	.22	2.26	.19	1.44	.15	.83	.11
8	5.38	.26	4.18	.23	2.89	.19	1.98	.16	1.26	.13	.73	.10
9	4.78	.23	3.71	.20	2.57	.17	1.76	.14	1.12	.12	.64	.09
10	4.31	.21	3.34	.18	2.31	.16	1.53	.13	1.01	.11	.58	.08
11	3.91	.19	3.04	.16	2.10	.14	1.44	.12	.92	.10	.53	.07
12	3.59	.18	2.78	.15	1.93	.13	1.32	.11	.84	.09	.48	.07
13	3.31	.16	2.57	.14	1.78	.12	1.22	.10	.78	.08	.45	.06
14	3.08	.15	2.39	.13	1.65	.11	1.13	.09	.72	.08	.41	.06
15	2.87	.14	2.23	.12	1.54	.10	1.05	.09	.67	.07	.39	.05
16	2.69	.13	2.09	.11	1.44	.10	.99	.08	.63	.07	.36	.05
17	2.53	.12	1.96	.11	1.36	.09	.93	.08	.59	.06	.34	.05
18	2.39	.11	1.86	.10	1.28	.09	.88	.07	.56	.06	.32	.04
19	2.27	.11	1.76	.09	1.22	.08	.83	.07	.53	.06	.31	.04
20	2.15	.11	1.67	.09	1.16	.08	.79	.07	.51	.05	.29	.04
21	2.05	.10	1.59	.09	1.10	.07	.75	.06	.48	.05	.28	.04
22	1.96	.10	1.52	.08	1.05	.07	.72	.06	.46	.05	.26	.04
23	1.87	.09	1.45	.08	1.00	.07	.69	.06	.44	.05	.25	.03
24	1.79	.09	1.39	.08	.96	.06	.66	.05	.42	.04	.24	.03
25	1.72	.08	1.34	.07	.92	.06	.63	.05	.40	.04	.23	.03

Safe loads given include weight of channel. Maximum fibre stress, 16,000 lbs. per square inch.

WEIGHT, STRENGTH, ETC., OF STANDARD HOISTING ROPE

Composed of Six Strands and a Hemp Centre, Nineteen Wires to the Strand

Trade Number.	Diameter in Inches.	Approximate Circumference in Inches.	Weight per Foot in Pounds.	Approximate Breaking Strain in Tons of 2000 Pounds.	Allowable Working Strain in Tons of 2000 Pounds.	Minimum Size of Drum or Sheave in Feet.
			Swedish Iron.			
..	2¾	8⅝	11.95	114	22.8	16
..	2½	7⅞	9.85	95	18.9	15
1	2¼	7⅛	8.00	78	15.60	13
2	2	6¼	6.30	62	12.40	12
3	1¾	5½	4.85	48	9.60	10
4	1⅝	5	4.15	42	8.40	8½
5	1½	4¾	3.55	36	7.20	7½
5½	1⅜	4¼	3.00	31	6.20	7
6	1¼	4	2.45	25	5.00	6½
7	1⅛	3½	2.00	21	4.20	6
8	1	3	1.58	17	3.40	5½
9	⅞	2¾	1.20	13	2.60	4½
10	¾	2¼	0.89	9.7	1.94	4
10¼	⅝	2	0.62	6.8	1.36	3½
10½	9/16	1¾	0.50	5.5	1.10	2¾
10¾	½	1½	0.39	4.4	0.88	2¼
10*a*	7/16	1¼	0.30	3.4	0.68	2
10*b*	⅜	1⅛	0.22	2.5	0.50	1½
10*c*	5/16	1	0.15	1.7	0.34	1
10*d*	¼	¾	0.10	1.2	0.24	¾
			Cast Steel.			
..	2¾	8⅝	11.95	223	45.6	10
..	2½	7⅞	9.85	190	37.9	9½
1	2¼	7⅛	8.00	156	31.2	8½
2	2	6¼	6.30	124	24.8	8
3	1¾	5½	4.85	96	19.2	7½
4	1⅝	5	4.15	84	16.8	6½
5	1½	4¾	3.55	72	14.4	5¾
5½	1⅜	4¼	3.00	62	12.4	5½
6	1¼	4	2.45	50	10.0	5
7	1⅛	3½	2.00	42	8.40	4½
8	1	3	1.58	34	6.80	4
9	⅞	2¾	1.20	26	5.20	3½
10	¾	2¼	0.89	19.4	3.88	3
10¼	⅝	2	0.62	13.6	2.72	2½
10½	9/16	1¾	0.50	11.0	2.20	1¾
10¾	½	1½	0.39	8.8	1.76	1½
10*a*	7/16	1¼	0.30	6.8	1.36	1¼
10*b*	⅜	1⅛	0.22	5.0	1.00	1
10*c*	5/16	1	0.15	3.4	0.68	¾
10*d*	¼	¾	0.10	2.4	0.48	½

WEIGHT, STRENGTH, ETC., OF EXTRA STRONG CRUCIBLE CAST-STEEL ROPE.

Composed of Six Strands and a Hemp Centre, Nineteen Wires to the Strand.

Trade Number.	Diameter in Inches.	Approximate Circumference in Inches.	Weight per Foot in Pounds.	Approximate Breaking Strain in Tons of 2000 Pounds.	Allowable Working Strain in Tons of 2000 Pounds.	Minimum Size of Drum or Sheave in Feet.
..	2¾	8⅝	11.95	266	53	10
..	2½	7⅞	9.85	222	45	9½
1	2¼	7⅛	8.00	182	36.4	8½
2	2	6¼	6.30	144	28.8	8
3	1¾	5½	4.85	112	22.4	7¼
4	1⅝	5	4.15	97	19.4	6½
5	1½	4¾	3.55	84	16.8	5¾
5½	1⅜	4¼	3.00	72	14.4	5½
6	1¼	4	2.45	58	11.6	5
7	1⅛	3½	2.00	49	9.80	4½
8	1	3	1.58	39	7.80	4
9	⅞	2¾	1.20	30	6.00	3½
10	¾	2¼	0.89	22	4.40	3
10¼	⅝	2	0.62	15.8	3.16	2½
10½	9/16	1¾	0.50	12.7	2.54	1¾
10¾	½	1½	0.39	10.1	2.02	1½
10*a*	7/16	1¼	0.30	7.8	1.56	1¼
10*b*	⅜	1⅛	0.22	5.78	1.15	1
10*c*	5/16	1	0.15	4.05	0.81	¾
10*d*	¼	¾	0.10	2.70	0.54	½

Seven Wires to the Strand.

Trade Number.	Diameter in Inches.	Approximate Circumference in Inches.	Weight per Foot in Pounds.	Approximate Breaking Strain in Tons of 2000 Pounds.	Allowable Working Strain in Tons of 2000 Pounds.	Minimum Size of Drum or Sheave in Feet.
11	1½	4¾	3.55	79	15.8	8½
12	1⅜	4¼	3.00	68	13.6	8
13	1¼	4	2.45	56	11.2	7¼
14	1⅛	3½	2.00	46	9.20	6¼
15	1	3	1.58	37	7.40	5¾
16	⅞	2¾	1.20	23	5.60	5
17	¾	2¼	0.89	21	4.20	4½
18	11/16	2⅛	0.75	18.4	3.68	4
19	⅝	2	0.62	15.1	3.02	3½
20	9/16	1¾	0.50	12.3	2.46	3
21	½	1½	0.39	9.70	1.94	2½
22	7/16	1¼	0.30	7.50	1.50	2¼
23	⅜	1⅛	0.22	5.58	1.11	2
24	5/16	1	0.15	3.88	0.77	1¾
25	9/32	⅞	0.125	3.22	0.64	1½

WEIGHT, STRENGTH, ETC., OF COPPER, IRON, TINNED AND GALVANIZED SASH-CORDS.

Composed of Six Strands and a Cotton Centre, Seven Wires to the Strand.

Trade Number.	Diameter in Inches.	Weight per Foot in Pounds.		Approximate Breaking Strain in Pounds.		
		Iron.	Copper.	Iron. Bright.	Iron. Annealed.	Bright Copper.
26	1/4	0.100	0.115	2200	1600	1265
27	7/32	0.076	0.087	1809	1254	1022
27½	3/16	0.056	0.064	1417	947	792
28	1/8	0.025	0.029	790	467	435
28½	3/32	0.014	0.016	510	280	272
29	1/16	0.006	0.007	262	132	140

APPROXIMATE WEIGHT AND STRENGTH OF MANILA ROPE.

Manila, Sisal, New Zealand, and Jute Ropes weigh (about) alike. Tarred Hemp Cordage will weigh (about) one-fourth more. Manila is about 25 per cent stronger than Sisal. Working load about one-fourth of breaking strain.

Circumference in Inches.	Diameter in Inches.	Weight of 1000 Feet in Pounds.	Number of Feet and Inches in One Pound.		Strength of New Manila Rope in Pounds.
			Ft.	Ins.	
¾	1/4	23	50		450
1	5/16	33	33		780
1⅛	3/8	42	25		1,000
1¼	7/16	52	19		1,280
1½	1/2	74	11		1,760
1¾	9/16	101	9		2,400
2	5/8	132	7		3,140
2¼	3/4	167	6		3,970
2½	13/16	207	5		4,900
2¾	7/8	250	4		5,900
3	1	297	3	6	7,000
3¼	1 1/16	349	2	10	8,200
3½	1⅛	405	2	4	9,600
3¾	1¼	465	2	1	11,000
4	1 5/16	529	1	10	12,500
4¼	1⅜	597	1	8	14,000
4½	1 7/16	669	1	5	15,800
4¾	1½	746	1	4	17,600
5	1⅝	826	1	2	19,500
5½	1¾	1000	1		23,700
6	1⅞	1190		10	28,000
6¼	2	1291		9½	33,000
6½	2⅛	1397		8½	38,000
7	2¼	1620		7	44,000
7½	2⅜	1860		6½	50,000
8	2 9/16	2116		5½	60,000
8½	2¾	2388		5	63,000
9	2⅞	2673		4½	67,700
9½	3	2983		4	70,000
10	3 3/16	3306		3⅝	78,000

STRENGTH OF MATERIALS.

Ultimate resistance to tension, in pounds per square inch.

METALS AND ALLOYS.

	Average.
Aluminum bronze:	
10 per cent Al and 90 per cent copper	85,000
$1\frac{1}{4}$ " " " $98\frac{1}{2}$ " "	28,000
Brass, cast	18,000
Brass wire	49,000
Bronze or gun metal	36,000
Copper, cast	19,000
Copper, sheet	30,000
Copper, bolts	36,000
Copper wire (unannealed)	60,000
Iron, cast, 13,400 to 29,000	16,500
Iron wire, black or annealed	56,000
Iron wire, bright, hard drawn	78,400
Lead, sheet	3,300
Steel	45,000 to 120,000
Steel aluminum, $2\frac{1}{8}$ per cent aluminum	70,000
Steel copper, 35 per cent copper	60,000
Steel nickel, $3\frac{1}{4}$ per cent nickel	86,000
Steel cast, wire Bessemer	2,896,000
Steel cast, wire high carbon	179,200
Steel cast, wire mild O. H.	134,000

The modulus of elasticity of steel from recent tests is from 27,000,000 to 31,000,000. Average, 29,000,000.

Tin, cast	4,600
Zinc	7,000 to 8,000

STONE, NATURAL AND ARTIFICIAL.

Brick and cement	280 to 300
Glass	2,560
Slate	2,400 to 4,600
Mortar, ordinary lime	10 to 20

ULTIMATE RESISTANCE TO COMPRESSION.

Metals.

Brass, cast	10,300
Iron, "	85,000 to 125,000
Steel	45,000 to 120,000

STONE, NATURAL AND ARTIFICIAL.

	Average.
Brick, weak	550 to 800
" strong	1,100
" fire	1,700
Brickwork, ordinary, in cement	300 to 600
" best	1,000
Glass	30,000
Granite	5,000 to 18,000
Limestone	4,000 to 16,000
Marble	4,000 to 18,000
Sandstone, ordinary	2,500 to 10,000

ULTIMATE RESISTANCE TO SHEARING.

Metals.

Iron, cast	25,000
Steel	50,000

MODULI OF ELASTICITY.

Metals.

Iron (cast)	12,000,000
Iron (wrought shapes)	27,000,000
Iron (rerolled bars)	26,000,000
Steel (casting)	30,000,000
Steel (structural)	29,000,000

COMPRESSIVE STRENGTH OF PORTLAND-CEMENT MORTAR IN POUNDS PER SQUARE INCH.

Age in			Neat.	1 Cement, 1 Sand.	1 Cement, 2 Sand.	1 Cement, 3 Sand.	1 Cement, 4 Sand.
Air.	Water.	Air.					
7	......	......	4970	2850	1370	....	473
1	6	......	6260	2880	1440	....	557
30	......	......	6140	3400	1490	....	656
1	29	......	8870	4680	2750	....	950
92	......	......	6080	3410	....	....	....
1	91	......	9560	....	....	....	....
1	91	2	....	7570	....	....	....
1	90	2	....	....	4990	....	....
93	......	......	....	....	2635	....	....
100	......	......	....	....	....	....	1030
101	......	......	....	....	....	1510	....
1	96	4	....	....	....	3140	....
1	95	4	....	....	....	....	1970
1	70	......	....	....	....	2570	....

WORKING STRENGTH OF VARIOUS BUILDING MATERIALS *

COMPRESSION (DIRECT).

STEEL AND IRON.

The safe carrying capacity of various building materials (except in case of columns) are as follows; the strength given being the working strength in pounds per square inch of section.

Rolled steel	16,000
Cast steel	16,000
Wrought iron	12,000
Cast iron (in short blocks)	16,000
Steel ribs and rivets (bearing)	20,000
Wrought-iron pins and rivets (bearing)	15,000

TIMBER.

	With Grain	Across Grain
Oak	900	800
Yellow pine	1000	600
White pine	800	400
Spruce	800	400
Locust	1200	1000
Chestnut	500	1000
Hemlock	500	500

CONCRETE.

Concrete (Portland) cement, 1; sand, 2; stone, 4	230
Concrete (Portland) cement, 1; sand, 2; stone, 5	208
Concrete (Rosendale), or equal, cement, 1; sand, 2; stone, 4	125
Concrete (Rosendale, or equal), cement, 1; sand, 2; stone, 5	111

STONEWORK

Rubble stonework in Portland cement-mortar	140
Rubble stonework in Rosendale cement-mortar	111
Rubble stonework in lime- and cement-mortar	97
Rubble stonework in lime-mortar	70

BRICKWORK.

Brickwork in Portland cement-mortar; cement, 1; sand, 3	250
Brickwork in Rosendale, or equal, cement-mortar, cement, 1; sand 3	208
Brickwork in lime- and cement-mortar; cement, 1; lime, 1; sand, 6	160
Brickwork in lime-mortar; lime, 1; sand, 4	111

* The stresses given in these tables are those recommended by the National Board of Fire Underwriters.

GRANITES, STONE, ETC.

Granites (according to test)	1000 to 2400
Gneiss stone	1200
Limestones (according to test)	700 to 2300
Marbles (according to test)	600 to 1200
Sandstones (according to test)	400 to 1600
Bluestone	2000
Brick (hard-burned, flatwise)	300
Slate	1000

SAFE EXTREME FIBRE STRESS (BENDING) OF VARIOUS MATERIALS IN POUNDS PER SQUARE INCH OF SECTION.

Rolled-steel beams	16,000
Rolled-steel pins, rivets, and bolts	20,000
Riveted-steel beams (net flange section)	14,000
Rolled wrought-iron beams	12,000
Rolled wrought-iron pins, rivets, and bolts	15,000
Riveted wrought-iron beams (net flange section)	12,000
Cast-iron compression side	16,000
Cast-iron tension side	3,000
Yellow pine	1,200
White pine	800
Spruce	800
Oak	1,000
Locust	1,200
Hemlock	600
Chestnut	800
Granite	180
Gneiss	150
Limestone	150
Slate	400
Marble	120
Sandstone	100
Bluestone	300
Concrete (Portland) cement, 1; sand, 2; stone, 4	30
Concrete (Portland) cement, 1; sand, 2; stone, 5	20
Concrete (Rosendale or equal) cement, 1; sand, 2; stone, 4	16
Concrete (Rosendale or equal) cement, 1; sand, 2; stone, 5	10
Brick (hard-burned)	50
Brickwork (in cement)	30

Tensile Working Strength of Various Materials in Pounds per Square Inch of Section.

Rolled steel	16,000
Cast steel	16,000
Wrought iron	12,000
Cast iron	3,000
Yellow pine	1,200
White pine	800
Spruce	800
Oak	1,000
Hemlock	600

Shear Working Strength of Various Materials in Pounds per Square Inch of Section.

Steel web-plates	9,000
Steel shop-rivets and pins	10,000
Steel field-rivets	8,000
Steel field-bolts	7,000
Wrought-iron web-plates	6,000
Wrought-iron shop-rivets and pins	7,500
Wrought-iron field-rivets	6,000
Wrought-iron field-bolts	5,500
Cast iron	3,000

	With Fibre.	Across Fibre.
Yellow pine	70	500
White pine	40	250
Spruce	50	320
Oak	100	600
Locust	100	720
Hemlock	40	275
Chestnut	40	150

Working Strength of Masonry.

The safe load for brickwork is

Eight tons per superficial foot when lime-mortar is used.

Eleven and one half tons per superficial foot when lime- and cement-mortar, mixed, are used.

Fifteen tons per superficial foot when cement-mortar is used.

RUBBLE STONEWORK.

The safe load for rubble stonework is

Ten tons per superficial foot when Portland cement is used.

Eight tons per superficial foot when natural cement is used.

Seven tons per superficial foot when lime- and cement-mortar, mixed, are used.

Five tons per superficial foot when lime-mortar is used.

CONCRETE.

The safe load for concrete is

Fifteen tons per superficial foot when Portland cement is used.

Eight tons per superficial foot when natural cement is used.

The above strength is for concrete, mixed, 1-3-5.

WORKING STRENGTH OF COLUMNS IN POUNDS PER SQUARE INCH OF SECTION.

Recommended by the National Board of Fire Underwriters.

When the Length Divided by Least Radius of Gyration equals	Working Stress per Square Inch of Section.		
	Cast Iron.	Steel.	Wrought Iron.
120	.....	8,240	4,400
110	.....	8,820	5,200
100	.....	9,400	6,000
90	.....	9,980	6,800
80	.....	10,560	7,600
70	9,200	11,104	8,400
60	9,500	11,720	9,200
50	9,800	12,300	10,000
40	10,100	12,880	10,800
30	10,400	13,460	11,600
20	10,700	14,040	12,400
10	11,000	14,620	13,200

And in like proportion for intermediate ratios.

When the Length Divided by the Least Diameter equals	Working Stress per Square Inch of Section.		
	Long-leaf Yellow Pine.	White Pine, Norway Pine, Spruce.	Oak.
30	460	350	390
25	550	425	475
20	640	500	560
15	730	575	645
12	784	620	696
10	820	650	730

And in like proportion for intermediate ratios. Five-eighth the values given for white pine shall also apply to chestnut and hemlock posts. For locust posts use one and one-half the value given for white pine.

WORKING STRENGTH (COMPRESSION) OF MASONRY AS ALLOWED BY THE BUILDING CODES OF VARIOUS CITIES.

Material.	Working Stress in Pounds per Square Inch of Section.			
	New York, 1902.	Chicago, 1905.	Philadelphia, 1902.	Cleveland, 1904.
Rubble stonework in Portland-cement mortar	140	....	139	139
Rubble stonework in Rosendale or equal cement mortar	111	....	139	97½
Rubble stonework in lime and cement mortar	97	....	111	69½
Rubble stonework in lime mortar	70	....	69½	55½
Rubble stonework, coursed, well bonded in lime mortar	....	....	....	83⅓
Rubble stonework, coursed, well bonded in lime and cement mortar	....	....	....	97½
Rubble stonework, coursed, well bonded in Rosendale or equal cement mortar	....	....	....	125
Rubble stonework, coursed, well bonded in Portland-cement mortar	....	....	....	152¾
Stone ashlar or blocks, with full beds in lime mortar	....	....	....	125
Stone ashlar or blocks, with full beds in lime and cement mortar	....	....	....	166⅔
Stone ashlar or blocks, with full beds in Rosendale or equal cement mortar	....	....	....	208⅓
Stone ashlar or blocks, with full beds in Portland-cement mortar	....	....	....	288
Dimension stones in cement mortar	....	139		
Dimension stones, dressed beds, in cement mortar	....	173½		
Granites (according to test)	1000–2400			
Greenwich stone	1200			
Gneiss (New York City)	1300			
Limestone (according to test)	700–2300			
Marble (according to test)	600–1200			
Sandstone (according to test)	400–1600			
Bluestone (North River)	2000			
Slate	1000			
Brickwork in Portland-cement mortar: cement, 1; sand, 3	250	173½	208	
Brickwork in Rosendale cement or equal mortar: cement, 1; sand, 3	208	125	208	
Brickwork in lime and cement mortar: cement, 1; lime, 1; sand, 6	160	....	167	
Brickwork in lime mortar: lime, 1; sand, 4	111	90	111	
Brick, common kiln run, in lime mortar	....	....	....	83⅓
Brick, common kiln run, in lime and cement mortar	....	....	....	111

WORKING STRENGTH (COMPRESSION) OF MASONRY—*Continued.*

Material.	Working Stress in Pounds per Square Inch of Section.			
	New York, 1902.	Chicago, 1905.	Philadelphia, 1902.	Cleveland, 1904.
Brick, common kiln run, in Rosendale or equal cement mortar...	....	....	....	139
Brick, common kiln run, in Portland-cement mortar..........	....	....	....	180½
Brick, common selected hard, in lime mortar................	....	....	....	111
Brick, common selected hard, in lime and cement mortar......	....	....	....	139
Brick, common selected hard, in Rosendale or equal cement mortar.....................	....	....	....	166⅔
Brick, common selected hard, in Portland-cement mortar......	....	....	....	202
Brick, hard, pressed, hydraulic, or vitrified shale or paving, in lime mortar................	....	....	....	139
Brick, hard, pressed, hydraulic, or vitrified shale or paving, in lime and cement mortar......	....	....	....	166⅔
Brick, hard, pressed, hydraulic, or vitrified shale or paving, in Rosendale or equal cement mortar..................	....	....	....	194½
Brick, hard, pressed, hydraulic, or vitrified shale or paving, in Portland-cement mortar.....	....	....	....	250

Note.—All brick acceptable under the New York Building Code must be good, hard, well-burned brick.

STRENGTH OF BRICK PIERS.

The late F. E. Kidder made some tests of brick piers laid up with various mortars, which at the age of about five months gave the following ultimate strength per square inch of section of the pier before failure:

Lime mortar, 3 parts; Portland cement, 1 part	3020 lbs.
Lime mortar, 3 parts; Newark and Rosendale cements, 1 part..	2552 "
Portland cement, 1 part; sand, 2 parts................	2500 "
Newark and Rosendale cements, 1 part; sand, 2 parts.	2135 "
Lime mortar, 3 parts; Roman cement, 1 part.........	2030 "
Roman cement, 1 part; sand, 2 parts.................	1927 "
Lime mortar.......................................	1562 "

The piers began to fail by cracking longitudinally at about one-half the ultimate strength.

WEIGHT OF VARIOUS MATERIALS AS COMPARED WITH WATER WEIGHING 62.5 LBS.

Names of Substances.	Specific Gravity.	Names of Substances.	Specific Gravity.
Aluminum cast	2.60	Mahogany	0.56–1.09
hammered	2.75	Maple, dry	0.70
Amber	1.08	Marble	2 52–2 85
Anthracite	1.40–1.70	Masonry, stone, dry	2.00–2.55
Asphaltum	1.10–1.20	" brick, "	1.50–1.60
Brass cast	8.40–8.70	Mercury at 32° Fahr.	13.596
rolled	8.57	Mica	2 80
Brick, common, hard	1.53–2 30	Nickel	8.8
Cement, ground, loose	1.85	Oak, dry	0.69–1.03
Charcoal	0.44	Petroleum at 59° Fahr.	0.80
Cherry, dry	0.76–0.84	Pine	0.35–0.60
Clay, dry	1.80–2.60	Platinum cast	21.15
Coal, bituminous	1.20–1.50	hammered	21.3–21.5
Coke, loose	0.55	Quartz	2.5–2.80
Concrete	2.47	Saltpetre, Chili	2.26
Copper cast	8.79	" Kali	1.95–2.08
rolled	8.78–9.00	Sand, fine, dry	1.40–1.65
Diamond	3.52	" wet	1.90–2.05
Earth, humus	1.30–1.80	" coarse	1.40–1.50
Glass, common window	2.64	Sandstone	2.20–2.50
Gneiss, common	2.40–2.70	Silver cast	10.48
Gold cast, pure, or 24 carat	19.28	hammered	10 62
pure, hammered	19 33	Slate	2.60–2 70
Granite	2.50–3.00	Snow, freshly fallen	0.19
Gypsum, cast, dry	0.97	Steel	7.26–7.86
Hornblende	3.00	Sulphur	1.93–2.07
Ice	0.88–0.92	Sodium	0.978
Iron cast	7.10–7.50	Tin cast	7.20
wrought	7.79	rolled	7.30
Ivory	1.82	Water, pure rain or distilled, at 39° F.	1.00
Lead	11.37	Water, sea	1.03
Lime	2.30–3.20	Walnut, dry	0.60–0 81
Lime, slaked	1.30–1.40	Wax	0.95–0.98
Limestones	2.46–2.84	Zinc cast	6.90
Magnesium	1.74	rolled	7.20

WEIGHT OF A CUBIC FOOT OF SUBSTANCES.

Names of Substances.	Average Weight, Pounds.
Aluminum	162
Anthracite, solid, of Pennsylvania	93
" broken, loose	54
" " moderately shaken	58
" heaped bushel, loose	(80)
Ash, American, white, dry	38
Asphaltum	87

WEIGHT OF A CUBIC FOOT OF SUBSTANCES—(*Continued*).

Names of Substances.	Average Weight, Pounds.
Brass (copper and zinc), cast	504
" rolled	524
Brick, best pressed	150
" common, hard	125
" soft, inferior	100
Brickwork, pressed brick	140
" ordinary	112
Cement, hydraulic, ground, loose, American Rosendale	56
" " " " " Louisville	50
" " " " English, Portland	90
Cherry, dry	42
Chestnut, dry	41
Clay, potters' dry	119
" in lump, loose	63
Coal, bituminous, solid	84
" " broken, loose	49
" " heaped bushel, loose	(74)
Coke, loose, of good coal	26.3
" " heaped bushel	(40)
Copper, cast	542
" rolled	548
Earth, common loam, dry, loose	76
" " " " moderately rammed	95
" as a soft, flowing mud	108
Ebony, dry	76
Elm, dry	35
Flint	162
Glass, common window	157
Gneiss, common	168
Gold, cast, pure, or 24 carat	1204
" pure, hammered	1217
Grain, at 60 lbs. per bushel	48
Granite	170
Gravel, about the same as sand, which see.	
Gypsum (plaster of Paris)	142
Hemlock, dry	25
Hickory, dry	53
Hornblende, black	203
Ice	58.7

WEIGHT OF A CUBIC FOOT OF SUBSTANCES—(*Continued*).

Names of Substances.	Average Weight, Pounds.
Iron, cast	450
" wrought, purest	485
" " average	480
Ivory	114
Lead	711
Lignum vitæ, dry	83
Lime, quick, ground, loose, or in small lumps	53
" " " " thoroughly shaken	75
" " " " per struck bushel	66
Limestones and marbles	168
" " " loose, in irregular fragments	96
Magnesium	109
Mahogany, Spanish, dry	53
" Honduras, dry	35
Maple, dry	45
Marbles, see Limestones.	
Masonry, of granite or limestone, well dressed	165
" " mortar rubble	154
" " dry " (well scabbled)	138
" " sandstone, well dressed	144
Mercury, at 32° Fahrenheit	849
Mica	183
Mortar, hardened	103
Mud, dry, close	80 to 110
Mud, wet, fluid, maximum	120
Oak, live, dry	59
Oak, white, dry	50
" other kinds	32 to 45
Petroleum	55
Pine, white, dry	25
" yellow, Northern	34
" " Southern	45
Platinum	1342
Quartz, common, pure	165
Rosin	69
Salt coarse, Syracuse, N. Y	45
" Liverpool, fine, for table use	49
Sand, of pure quartz, dry, loose	90 to 106
" well shaken	99 to 117

WEIGHT OF A CUBIC FOOT OF SUBSTANCES—(*Continued*).

Names of Substances.	Average Weight, Pounds.
Sand, perfectly wet	120 to 140
Sandstones, fit for building	151
Shales, red or black	162
Silver	655
Slate	175
Snow, freshly fallen	5 to 12
" moistened and compacted by rain	15 to 50
Spruce, dry	25
Steel	490
Sulphur	125
Sycamore, dry	37
Tar	62
Tin, cast	459
Turf or peat, dry, unpressed	20 to 30
Walnut, black, dry	38
Water, pure rain or distilled, at 60° Fahrenheit	62⅓
" sea	64
Wax, bees	60.5
Zinc or spelter	437.5

Green timbers usually weigh from one-fifth to one-half more than dry

WEIGHT OF DIFFERENT MATERIALS.

	Pounds.
1 barrel of lime	200 to 230
1 " " cement (hydraulic or Rosendale)	300
1 " " " (Portland)	400
1 " " " (Scotch, Roman)	350
1 " " fire-clay (American)	300
1 " " " (English)	350
1 " " brick-dust	350
1 " " marble-dust	350
1 " " plaster, California	260
1 " " " Wotherspoon (Eastern)	275
1 " " " (ground gypsum or land)	320

Fire-brick 6½ to 7 pounds each.

APPROXIMATE WEIGHT OF VARIOUS ROOF COVERINGS.

Material.	Weight in Pounds per Square of Roof.
Yellow pine (Northern) sheathing 1 inch thick	300
" " (Southern)	400
Spruce	200
Chestnut or maple	400
Ash or oak	500
Shingles, pine	200
Slate $\frac{1}{4}$ inch thick	900
Sheet iron $\frac{1}{16}$ inch thick	300
" " $\frac{1}{16}$ inch " and laths	500
Iron, corrugated	100 to 375
" galvanized, flat	100 to 350
Tin	70 to 125
Felt and asphalt	100
" " gravel	800 to 1000
Skylights, glass, $\frac{3}{16}$ inch to $\frac{1}{2}$ inch thick	250 to 700
Sheet lead	500 to 800
Copper	80 to 125
Zinc	100 to 200
Tiles, flat	1500 to 2000
" " with mortar	2000 to 3000
" pan	1000

ANGLES OF ROOFS AS COMMONLY USED.

Proportion of Rise to Span.	Angle.		Length of Rafter to Rise.	Proportion of Rise to Span.	Angle.		Length of Rafter to Rise.
	Deg.	Min.			Deg.	Min.	
$\frac{1}{2}$	45	..	1.4142	$\frac{1}{4}$	26	34	2.2361
$\frac{1}{3}$	33	41	1.8028	$\frac{1}{5}$	21	48	2.6926
$\frac{1}{2\sqrt{3}}$	30	..	2.0000	$\frac{1}{6}$	18	26	3.1623

WEIGHTS AND MEASURES OF CONCRETE MATERIALS.

Sand weighs from 80 to 100 pounds per cubic foot, dry and loose, and from 90 to 115 pounds, dry and well shaken.

Gravel weighs from 100 to 120 pounds per cubic foot loose, and about 20 pounds more when well rammed.

Crushed limestone weighs about 90 pounds per cubic foot, varying somewhat either way with the size and the proportion of fine dust.

Copper slag, which has been used successfully where weight is wanted in concrete, weighs 120 to 125 pounds per cubic foot

Quicklime weighs 64 pounds per cubic foot.

Portland cement, loose, weighs 70 to 90 pounds per cubic foot; packed, about 110 pounds per cubic foot.

ESTIMATED WEIGHTS OF LUMBER.

PER THOUSAND FEET.

	Dry, Pounds.	Green, Pounds.
Black ash	3250	4500
White ash	3500	4500
Beech	4000	6000
Basswood	2400	4000
Birch	4000	5500
Butternut	2500	4000
Cherry	3800	5000
Chestnut	2800	5000
Cypress	3000	5000
Cottonwood	2800	4500
Rock elm	4000	5500
Soft elm	3000	4500
Gum	3300	5500
Hickory	4500	6000
Mahogany	3500	4500
Maple	4000	5500
Oak	4000	5500
Poplar	2800	3800
Sycamore	3000	4750
Walnut	3800	4800
Yellow pine	3200	4300

WEIGHTS OF PACIFIC-COAST LUMBER.

	Pounds per Thousand Feet.
Oregon fir, 1 inch, rough	2200
Washington red cedar, 1 inch, rough	2300
Washington red cedar, 1 inch, dressed	2000
California sugar pine, 1 inch, rough	2200
California redwood, 1 to 2 inch, rough	2500
California redwood, 1 to 2 inch, S 1 S	2200
California redwood, 1 to 2 inch, S 2 S	2000
Cedar shingles, *A*	200

CARRYING POWER OF PILES.

The following table and formula taken from *Engineering News* has been used by a number of engineers and has been pronounced very reliable. The table is for spruce piles and average penetration during last five blows of a 1200-pound hammer dropping 15 feet.

BEARING VALUE OF PILES.

Nature of Soil.	Length of Pile in Feet.	Average Diameter in Inches.	Penetration in Inches.	Load in Tons.
Silt	40	10	6	2.75
Mud	30	8	2	6
Soft earth with boulders and logs	30	8	1.5	7.2
Moderately firm earth or clay with boulders and logs	30	8	1	9
Soft earth or clay	30	10	1	9
Quicksand	30	8	.5	12
Firm earth	30	8	.5	12
Firm earth into sand or gravel	20	8	.25	14
Firm earth to rock	20	8	0	18
Sand	20	8	0	18
Gravel	15	8	0	18

The formula is:

$$\text{Safe load in pounds} = \frac{2WH}{S+1},$$

in which W equals weight of the hammer in pounds, H its fall in feet, S average penetration in inches during last five blows.

CARRYING POWER OF SOILS, ETC.

Name of Soil, etc.	Carrying Power per Square Foot.
Rock, hard, on native bed	250 tons
Ledge rock	36 "
Hard-pan	8 "
Gravel	5 "
Clean sand	4 "
Dry clay	3 "
Wet clay	2 "
Loam	1 ton

APPROXIMATE LOADS PER SQUARE FOOT FOR ROOFS OF SPANS UNDER SEVENTY-FIVE FEET, INCLUDING WEIGHT OF TRUSS.

Roof covered with corrugated sheets, unboarded...	8	pounds.
" " " " " on boards....	11	"
" " " slate, on laths..................	13	"
Same, on boards $1\frac{1}{4}$ in. thick..........................	16	"
Roof covered with shingles, on laths..............	10	"
Add to above, if plastered below rafters..........	10	"
Snow, light, weighs per cubic foot...........	5 to 12	"

For spans over 75 feet add 4 pounds to the above loads per square foot.

It is customary to add 30 pounds per square foot to the above for snow and wind when separate calculations are not made.

PRESSURE OF WIND ON ROOFS. (Unwin.)

a = angle of surface of roof with direction of wind;
F = force of wind in pounds per square foot;
A = pressure normal to surface of roof $= F \sin a^{1.84 \cos a - 1}$.
B = pressure perpendicular to direction of wind $= F \cot a \sin a^{1.84 \cos a}$.
C = pressure parallel to direction of wind $= F \sin a^{1.84 \cos a}$.

Angle of roof $= a$.......	5°	10°	20°	30°	40°	50°	60°	70°	80°	90°
$A = F \times$..............	.125	.2	.45	.66	.83	.95	1.00	1.02	1.01	1.00
$B = F \times$..............	.122	.24	.42	.57	.64	.61	.50	.35	.17	.00
$C = F \times$..............	.01	.04	.15	.33	.53	.73	.85	.96	.99	1.00

RELATIVE WEIGHTS OF METALS.

Cubic inches multiplied by:
.263 = pounds of cast iron
.281 = " " wrought iron
.283 = " " steel
.3225 = " " copper
.3037 = " " brass
.26 = " " zinc
.4103 = " " lead
.2636 = " " tin
.4908 = " " mercury

Cylindrical inches multiplied by:
.2065 = pounds of cast iron
.2168 = " " wrought iron
.2223 = " " steel
.2533 = " " copper
.2385 = " " brass
.2042 = " " zinc
.3223 = " " lead
.207 = " " tin
.3854 = " " mercury

WEIGHT IN POUNDS OF 100 BOLTS WITH SQUARE HEADS AND NUTS.

One cubic foot weighing 480 lbs.

Length.	Diameter of Bolt, Inches.								
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
$1\frac{1}{2}$	4.0	6.8	10.6	15.0	23.9	40.5	70.0		
$1\frac{3}{4}$	4.4	7.3	11.3	16.1	25.1	42.7	73.1		
2	4.7	7.8	12.0	17.2	26.3	44.8	76.2		
$2\frac{1}{4}$	5.1	8.4	12.6	18.2	27.7	47.0	79.3		
$2\frac{1}{2}$	5.4	8.9	13.3	19.2	29.0	49.2	82.4	120.5	
$2\frac{3}{4}$	5.8	9.5	14.0	20.2	30.4	51.4	85.5	124.7	
3	6.1	10.0	14.7	21.2	31.8	53.5	88.7	128.9	185.0
$3\frac{1}{2}$	6.8	11.1	16.0	23.2	34.7	57.9	95.0	137.4	196.0
4	7.5	12.2	17.4	25.2	37.5	62.3	101.2	145.8	207.0
$4\frac{1}{2}$	8.2	13.2	18.7	27.2	40.2	66.7	107.5	159.2	218.0
5	8.9	14.3	20.0	29.1	43.0	71.0	113.7	167.7	229.0
$5\frac{1}{2}$	9.6	15.4	21.4	31.2	45.7	75.4	120.0	176.1	240.0
6	10.3	16.5	22.8	33.1	48.4	79.8	126.2	184.6	251.0
$6\frac{1}{2}$	11.0	17.6	24.1	35.1	51.2	84.1	132.5	193.0	262.0
7	11.7	18.6	25.9	37.1	54.0	88.5	138.7	201.4	273.0
$7\frac{1}{2}$	12.4	19.7	27.7	39.1	56.7	92.9	145.0	209.9	284.0
8	13.1	20.8	29.5	41.0	59.4	97.2	151.2	218.3	295.0
9	.....	......	33.1	45.0	64.8	106.0	163.7	240.2	317.0
10	.....	......	36.7	49.0	70.3	114.7	176.2	257.1	339.0
11	.....	......	40.4	53.0	75.8	123.5	188.7	273.9	360.0
12	.....	......	44.0	57.0	81.3	132.2	201.0	290.0	382.0
13	.....	......	......	......	86.7	140.7	213.4	307.7	404.0
14	.....	......	......	......	92.2	149.2	225.9	324.5	426.0
15	.....	......	......	......	97.7	157.6	238.3	341.4	448.0
16	.....	......	......	......	103.1	166.1	250.8	358.3	470.0
17	.....	......	......	......	108.6	174.6	263.2	375.2	492.0
18	.....	......	......	......	114.1	183.1	275.6	392.0	514.0
19	.....	......	......	......	119.5	191.5	288.1	408.9	536.0
20	.....	......	......	......	125.0	200.0	300.5	425.8	558.0
Per in. additional.	1.4	2.2	3.6	4.0	5.5	8.5	12.4	16.9	22.0

APPROXIMATE WEIGHT OF NUTS AND BOLT HEADS IN POUNDS.

Diam. of Bolt in Ins.	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$
Weight of hexagon nut and head	0.017	0.042	0.057	0.109	0.128	0.267	0.43
Weight of square nut and head	0.021	0.049	0.069	0.120	0.164	0.320	0.55
Diam. of Bolt in Ins.	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$
Weight of hexagon nut and head	0.73	1.10	2.14	3.78	5.6	8.75	17.0
Weight of square nut and head	0.88	1.31	2.56	4.42	7.0	10.5	21.0

BOARD MEASURE.

Explanation.—In the following tables to find the contents of any piece of lumber find the size of the piece in the column under size in inches, and in the column under the length of the piece of lumber in feet will be found the contents in board measure.

Size in Inches.	Length in Feet.																	
	5		6		7		8		9		10		11		12		13	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
1×3	1	3	1	6	1	9	2		2	3	2	6	2	9	3		3	3
1×4	1	8	2		2	4	2	8	3		3	4	3	8	4		4	4
1×5	2	1	2	6	2	11	3	4	3	9	4	2	4	7	5		5	5
1×6	2	6	3		3	6	4		4	6	5		5	6	6		6	6
1×7	2	11	3	6	4	1	4	8	5	3	5	10	6	5	7		7	7
1×8	3	4	4		4	8	5	4	6		6	8	7	4	8		8	8
1×9	3	9	4	6	5	3	6		6	9	7	6	8	3	9		9	9
1×10	4	2	5		5	10	6	8	7	6	8	4	9	2	10		10	10
1×11	4	7	5	6	6	5	7	4	8	3	9	2	10	1	11		11	11
1×12	5		6		7		8		9		10		11		12		13	
1×13	5	5	6	6	7	7	8	8	9	9	10	10	11	11	13		14	1
1×14	5	10	7		8	2	9	4	10	6	11	8	12	10	14		15	2
1×15	6	3	7	6	8	9	10		11	3	12	6	13	9	15		16	3
1×16	6	8	8		9	4	10	8	12		13	4	14	8	16		17	4
1×17	7	1	8	6	9	11	11	4	12	9	14	2	15	7	17		18	5
1×18	7	6	9		10	6	12		13	6	15		16	6	18		19	6
1×19	7	11	9	6	11	1	12	8	14	3	15	10	17	5	19		20	7
1×20	8	4	10		11	8	13	4	15		16	8	18	4	20		21	8
1×21	8	9	10	6	12	3	14		15	9	17	6	19	3	21		22	9
1×22	9	2	11		12	10	14	8	16	6	18	4	20	2	22		23	10
1×23	9	7	11	6	13	5	15	4	17	3	19	2	21	1	23		24	11
1×24	10		12		14		16		18		20		22		24		26	
1×25	10	5	12	6	14	7	16	8	18	9	20	10	22	11	25		27	1
1×26	10	10	13		15	2	17	4	19	6	21	8	23	10	26		28	2

Size in Inches.	Length in Feet.																	
	14		15		16		17		18		19		20		21		22	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
1×3	3	6	3	9	4		4	3	4	6	4	9	5		5	3	5	6
1×4	4	8	5		5	4	5	7	6		6	4	6	8	7		7	5
1×5	5	10	6	3	6	8	7	1	7	3	7	11	8	4	8	9	9	2
1×6	7		7	6	8		8	6	9		9	6	10		10	6	11	
1×7	8	2	8	9	9	4	9	11	10	6	11	1	11	8	12	3	12	10
1×8	9	4	10		10	8	11	4	12		12	8	13	4	14		14	8
1×9	10	6	11	3	12		12	9	13	6	14	3	15		15	9	16	6
1×10	11	8	12	6	13	4	14	2	15		15	10	16	8	17	6	18	4
1×11	12	10	13	9	14	8	15	7	16	6	17	5	18	4	19	3	20	
1×12	14		15		16		17		18		19		20		21		22	
1×13	15	2	16	3	17	4	18	5	19	6	20	7	21	8	22	9	23	10
1×14	16	4	17	6	18	8	19	10	21		22	2	22	4	24	6	25	8
1×15	17	6	18	9	20		21	3	22	6	23	9	25		26	3	27	6
1×16	18	8	20		21	4	22	8	24		25	4	26	8	28		29	4
1×17	19	10	21	3	22	8	24	1	25	6	26	11	28	4	29	9	31	2
1×18	21		22	6	24		25	6	27		28	6	30		31	6	33	
1×19	22	2	23	9	25	4	26	11	28	6	30	1	31	8	33	3	34	10
1×20	23	4	25		26	8	28	4	30		31	8	33	4	35		36	8
1×21	24	6	26	3	28		29	9	31	6	33	3	35		36	9	38	6
1×22	25	8	27	6	29	4	31	2	33		34	10	36	8	38	6	40	4
1×23	26	10	28	9	30	8	32	7	34	6	36	5	38	4	40	3	43	2
1×24	28		30		32		34		36		38		40		42		44	
1×25	29	2	31	3	33	4	35	5	37	6	39	7	41	8	43	9	45	10
1×26	30	4	32	6	34	8	36	10	39		41	2	43	4	45	6	47	8

SCANTLINGS AND PLANKS REDUCED TO BOARD MEASURE.

Size in Inches.	Length in Feet.																	
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	24	26
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
1½ × 2	1 3	1 6	1 9	2	2 3	2 6	2 9	3	3 3	3 6	3 9	4	4 3	4 6	5	5 6	6	6 6
1½ × 3	1 11	2 3	2 8	3	3 5	3 9	4 2	4 6	4 11	5 3	5 8	6	12 5	6 11	7 6	8 3	9	9 9
1½ × 4	2 6	3	3 6	4	4 6	5	5 6	6	6 6	7	7 6	8	8 6	9	10	11	12	13
1½ × 5	3 2	3 9	4 5	5	5 8	6 3	6 11	7 6	8 2	7 9	9 5	10	10 8	11 3	12 6	13 9	15	16 3
1½ × 6	3 9	4 6	5 3	6	6 9	7 6	8 3	9	9 9	10 6	11 3	12	12 9	13 6	15	16 6	18	19 6
1½ × 7	4 5	5 3	6 2	7	7 11	8 9	9 8	10 6	11 5	12 3	13 2	14	14 11	15 9	17 6	20 2	21	22 9
1½ × 8	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	22	24	26
1½ × 9	5 8	6 9	7 11	9	10 2	11 3	12 5	13 6	14 8	14 9	16 11	18	19 2	20 3	22 6	24 9	27	29 3
1½ × 10	6 3	7 6	8 9	10	11 3	12 6	13 9	15	16 3	17 6	18 9	20	21 3	22 6	25	27 6	30	32 6
1½ × 12	7 6	9	10 6	12	13 6	15	16 6	18	19 6	21	22 6	24	25 [illegible]	27	33	33	36	39
1½ × 14	8 9	10 6	12 3	14	15 9	17 6	19 3	21	22 9	24 6	26 3	28	29 9	31 6	35	38 6	42	45 6
1½ × 16	10	12	14	16	18	20	22	24	26	28	30	32	34	36	40	44	48	52

Size in Inches.	Length in Feet.																	
	7	8	9	10	11	12	13	14	15	16	18	20	22	24	26	28	30	32
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
2 × 2	2 4	2 8	3	3 4	3 8	4	4 4	4 8	5	5 4	6	6 8	7 4	8	8 8	9 4	10	10 8
2 × 3	3 6	4	4 6	5	5 6	6	6 6	7	7 6	8	9	10	11	12	13	14	15	16
2 × 4	4 8	5 4	6	6 8	7 4	8	8 8	9 4	10	10 8	12	13 4	14 8	16	17 4	18 8	20	21 4
2 × 5	5 10	6 8	7 6	8 4	9 2	10	10 10	11 8	12 6	13 4	15	16 8	18 4	20	21 8	23 4	25	26 8
2 × 6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	26	28	30	32
2 × 7	8 2	9 4	10 6	11 8	12 10	14	15 2	16 4	17 6	18 8	21	23 4	25 8	28	30 4	32 8	35	37 4
2 × 8	9 4	10 8	12	13 4	14 8	16	17 4	18 8	20	21 4	24	26 8	29 4	32	34 8	37 4	40	42 8
2 × 10	11 8	13 4	15	16 8	18 4	20	21 8	23 4	25	26 8	30	33 4	36 8	40	43 4	46 8	50	53 4
2 × 12	14	16	18	20	22	24	26	28	30	32	36	40	44	48	52	56	60	64
2 × 14	16 4	18 8	21	23 4	25 8	28	30 4	32 8	35	37 4	42	46 8	51 4	56	60 8	65 4	70	74 8
2 × 16	18 8	21 4	24	26 8	29 4	32	34 8	37 4	40	42 8	48	53 4	58 8	64	69 4	74 8	80	85 4
2 × 18	21	24	27	30	33	36	39	42	45	48	54	60	66	72	78	84	90	96

SCANTLINGS AND PLANKS REDUCED TO BOARD MEASURE—(*Continued*).

Length in Feet.

Size in Inches.	8		9		10		11		12		13		14		15		16	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
2½ × 2	3	4	3	9	4	2	4	7	5		5	5	5	10	6	3	6	8
2½ × 3	5		5	8	6	3	6	11	7	6	8	2	8	9	9	5	10	
2½ × 4	6	8	7	6	8	4	9	2	10		10	10	11	8	12	6	13	4
2½ × 5	8	4	9	5	10	5	11	6	12	6	13	7	14	7	15	8	16	8
2½ × 6	10		11	3	12	6	13	9	15		16	3	17	6	18	9	20	
2½ × 7	11	8	13	2	14	7	16	1	17	6	19		20	5	21	11	23	4
2½ × 8	13	4	15		16	8	18	4	20		21	8	23	4	25		26	8
2½ × 10	16	8	18	9	20	10	22	11	25		27	1	29	2	31	3	33	4
2½ × 12	20		22	6	25		27	6	30		32	6	35		37	6	40	
2½ × 14	23	4	26	3	29	2	32	1	35		37	11	40	10	43	9	46	8
2½ × 16	26	8	30		33	4	36	8	40		43	4	46	8	50		53	4
2½ × 18	30		33	9	37	6	41	3	45		48	9	52	6	56	3	60	
3 × 3	6		6	9	7	6	8	3	9		9	9	10	6	11	3	12	
3 × 4	8		9		10		11		12		13		14		15		16	
3 × 5	10		11	3	12	6	13	9	15		16	3	17	6	18	9	20	
3 × 6	12		13	6	15		16	6	18		19	6	21		22	6	24	
3 × 7	14		15	9	17	6	19	3	21		22	9	24	6	26	3	28	
3 × 8	16		18		20		22		24		26		28		30		32	
3 × 10	20		22	6	25		27	6	30		32	6	35		37	6	40	
3 × 12	24		27		30		33		36		39		42		45		48	
3 × 14	28		31	6	35		38	6	42		45	6	49		52	6	56	
3 × 15	30		33	9	37	6	41	3	45		48	9	52	6	56	3	60	
3 × 16	32		36		40		44		48		52		56		60		64	
3 × 18	36		40	6	45		49	6	54		58	6	63		67	6	72	

Size in Inches.	18		20		22		24		26		28		30		32		34	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
2½ × 2	7	6	8	4	9	2	10		10	10	11	8	12	6	13	4	14	2
2½ × 3	11	4	12	6	13	10	15		16	4	17	6	18	9	20		21	3
2½ × 4	15		16	8	18	4	20		21	8	23	4	25		26	8	28	4
2½ × 5	18	9	20	10	22	11	25		27	1	29	2	31	3	33	4	35	5
2½ × 6	22	6	25		27	6	30		32	6	35		37	6	40		42	6
2½ × 7	26	3	29	2	32	1	35		37	11	40	10	43	9	46	8	49	7
2½ × 8	30		33	4	36	8	40		43	4	46	8	50		53	4	56	8
2½ × 10	37	6	41	8	45	10	50		54	2	58	4	62	6	66	8	70	10
2½ × 12	45		50		55		60		65		70		75		80		85	
2½ × 14	52	6	58	4	64	2	70		75	10	81	8	87	6	93	4	99	2
2½ × 16	60		66	8	73	4	80		86	8	93	4	100		106	8	113	4
2½ × 18	67	6	75		82	6	90		97	6	105		112	6	120		126	6
3 × 3	13	6	15		16	6	18		19	6	21		22	6	24		25	6
3 × 4	18		20		22		24		26		28		30		32		34	
3 × 5	22	6	25		27	6	30		32	6	35		37	6	40		42	6
3 × 6	27		30		33		36		39		42		45		48		51	
3 × 7	31	6	35		38	6	42		45	6	49		52	6	56		59	6
3 × 8	36		40		44		48		52		56		60		64		68	
3 × 10	45		50		55		60		65		70		75		80		85	
3 × 12	54		60		66		72		78		84		90		96		112	
3 × 14	63		70		77		84		91		98		105		112		119	
3 × 15	67	6	75		82	6	90		97	6	105		112	6	120		127	6
3 × 16	72		80		88		96		112		118		124		130		136	
3 × 18	81		90		99		108		117		126		135		144		153	

SCANTLINGS AND PLANKS REDUCED TO BOARD MEASURE—(*Continued*).

Size in Inches	Length in Feet.																																	
	8		9		10		11		12		14		16		18		20		22		24		26		28		30		32		34		36	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
4× 4	10	8	12		13	4	14	8	16		18	8	21	4	24		26	8	29	4	32		34	8	37	4	40		42	8	45	4	48	
4× 5	13	4	15		16	8	18	4	20		23	14	26	8	30		33	4	40		40		43	4	46	8	50		53	4	56	8	60	
4× 6	16		18		20		22		24		28		32		36		40		44		48		52		56		60		64		68		72	
4× 8	21	4	24		26	8	29	4	32		37	4	42	8	48	4	53	4	58	8	64		69	4	74	8	80		85	4	90	8	96	
4×10	26	8	30		33	4	36	8	40		46	8	53	4	60		66	8	73	4	80		86	8	93	4	100		106	8	113	4	120	
4×12	32		36		40		44		48		56		64		72		80		88		96		104		112		120		128		136		144	
4×14	37	4	42		46	8	51	4	56		65	4	74	8	84		93	4	102	8	112		121	4	130	8	140		149	4	158	8	168	
4×16	42	8	48		53	4	58	8	64		74	8	85	4	96		106	8	117	4	128		138	8	149	4	160		170	8	181	4	192	
4×18	48		54		60		66		72		84		96		108		120		132		144		156		168		180		192		204		216	
4×20	53	4	60		66	8	73	4	80		93	4	106	8	120	4	133	4	146	8	160		173	4	186	8	200		213	4	226	8	240	
4×22	58	8	66		73	4	80	8	88		102	8	117	4	132		146	8	161	4	176		190	8	205	4	220		234	8	249	4	264	
4×24	64		72		80		88		96		112		128		144		160		176		192		208		224		240		256		272		288	
5× 5	16	8	18	9	20	10	22	11	25		29	2	33	4	37	6	41	8	45	10	50		54	2	58	4	62	6	66	8	70	10	75	
5× 6	20		22	6	25		27	6	30		35		40		45		50		55		60		65		70		75		80		85		90	
5× 7	23	4	26	3	29	2	32	1	35		40	10	46	8	52	6	58	4	64	2	70		75	10	81	8	87	6	93	4	99	2	105	
5× 8	26	8	30		33	4	36	8	40		46	8	53	4	60		66	8	73	4	80		86	8	93	4	100		106	8	113	4	120	
5×10	33	4	37	6	41	8	45	10	50		58	4	66	8	75		83	4	91	8	100		108	4	116	8	125		133	4	141	8	150	
5×12	40		45		50		55		60		70		80		90		100		110		120		130		140		150		160		170		180	
5×14	46	8	52	6	58	4	64	2	70		81	8	93	4	105		116	8	128	4	140		151	8	163	4	175		186	8	193	4	210	
5×16	53	4	60		66	8	73	4	80		93	4	106	8	120		133	4	146	8	160		173	4	186	8	200		213	4	226	8	240	
5×18	60		67	6	75		82	6	90		105		120		135		150		165		180		195		210		225		240		255		270	
5×20	66	8	75		83	4	91	8	100		116	8	133	4	150		166	8	183	4	200		216	8	233	4	250		266	8	283	4	300	
5×22	73	4	82	6	91	8	100	10	110		128	4	146	8	165		183	4	201	8	220		238	4	256	8	275		293	4	311	8	330	
5×24	80		90		100		110		120		140		160		180		200		220		240		260		280		300		320		340		360	

TIMBER REDUCED TO BOARD MEASURE.

Size in Inches.	Length in Feet.															
	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
6× 6	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114
6× 8	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152
6×10	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190
6×12	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228
6×14	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266
6×16	64	80	93	112	128	144	160	176	192	208	224	240	256	272	288	304
6×18	72	90	108	126	144	162	180	198	216	234	252	270	283	306	324	342
6×20	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380
6×22	88	110	132	154	176	198	220	242	264	286	308	330	352	374	396	418
6×24	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456
7× 8	37 4	46 8	56	65 4	74 8	84	93 4	102 8	112	121 4	130 8	140	149 4	158 8	168	177 4
7×10	46 8	58 4	70	81 8	93 4	105	116 8	128 4	140	151 8	163 4	175	186 8	198 4	210	221 8
7×12	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266
7×14	65 4	81 8	98	114 4	130 8	147	163 4	179 8	196	212 4	228 8	245	261 4	277 8	294	310 4
7×16	74 8	93 4	112	130 8	149 4	168	186 8	205 4	224	242 8	261 4	280	298 8	317 4	336	354 8
7×18	84	105	126	147	168	189	210	231	252	273	294	315	336	357	378	399
7×20	93 4	116 8	140	163 4	186 8	210	233 4	256 8	280	303 4	326 8	350	373 4	396 8	420	443 4
7×22	102 8	128 4	154	179 8	205 4	231	256 8	282 4	308	333 8	359 4	385	410 8	436 4	462	487 8
7×24	112	140	168	296	224	252	280	308	336	364	392	420	448	476	504	532
8× 8	42 8	53 4	64	74 8	85 4	96	106 8	117 4	128	138 8	149 4	160	170 8	181 4	192	202 8
8×10	53 4	60 8	80	93 4	106 8	120	133 4	146 8	160	173 4	186 8	200	213 4	226 8	240	253 4
8×12	64	80	96	112	128	144	1 0	176	192	208	224	240	256	272	288	304
8×14	74 8	93 4	112	130 8	149 4	168	186 8	205 4	224	242 8	261 4	280	298 8	317 4	336	354 8
8×16	85 4	106 8	128	149 4	170 8	192	213 4	234 8	256	277 4	298 8	320	341 4	362 8	384	405 4
8×18	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456
8×20	106 8	133 4	160	186 8	213 4	240	266 8	293 4	320	346 8	373 4	400	426 8	453 4	480	506 8
8×22	117 4	146 8	176	205 4	234 8	264	293 4	322 8	352	381 4	410 8	440	469 4	498 8	528	557 4
8×24	128	160	192	224	256	288	320	352	384	416	448	480	512	544	576	603

TIMBER REDUCED TO BOARD MEASURE—(*Continued*).

Size in Inches.	Length in Feet.															
	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
9×9	67 6	81	94 6	108	121 6	135	148 6	162	175 6	189	202 6	216	229 6	243	256 6	270
9×10	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300
9×12	90	103	126	144	162	180	198	216	234	252	270	288	306	324	342	360
9×14	105	126	147	168	189	210	231	252	273	294	315	336	357	378	399	420
9×16	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480
9×18	135	162	189	216	243	270	297	324	351	378	405	432	459	486	513	540
9×20	150	180	205	240	270	300	330	360	390	420	450	480	510	540	570	600
9×22	165	198	227	264	297	330	363	396	429	462	495	528	561	594	627	660
9×24	180	216	252	288	324	360	396	432	468	504	540	576	612	648	684	720
10×10	83 4	100	116 8	133 4	150	166 8	183 4	200	216 8	233 4	250	266 8	283 4	300	316 8	333 4
10×12	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
10×14	116 8	140	163 4	186 8	210	233 4	256 8	280	303 4	326 8	350	373 4	396 8	420	443 4	466 8
10×16	133 4	160	186 8	213 4	240	266 8	293 4	320	346 8	373 4	400	426 8	453 4	480	506 8	533 4
10×18	150	180	205	240	270	300	330	360	390	420	450	480	510	540	570	600
10×20	166 8	200	233 4	266 8	300	333 4	366 8	400	433 4	466 8	500	533 4	566 8	600	633 4	666 8
10×22	183 4	220	256 8	293 4	330	366 8	403 4	440	476 8	513 4	550	586 8	623 4	660	696 8	733 4
12×12	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480
12×14	140	168	296	224	252	280	308	336	364	392	420	448	476	504	532	560
12×16	160	192	224	256	288	320	352	384	416	448	480	512	544	576	608	640
12×18	180	216	252	288	324	360	396	432	468	504	540	576	612	648	684	720
12×20	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800
14×14	163 4	196	228 8	261 4	294	326 8	359 4	392	424 8	457 4	490	522 8	555 4	588	620 8	653 4
16×16	213 4	256	298 8	341 4	384	427 8	469 4	512	554 8	597 4	640	682 8	625 4	768	810 8	853 4
18×18	270	324	378	432	486	540	594	648	702	756	810	864	918	972	1026	1080
20×20	333 4	400	466 8	533 4	600	666 8	733 4	800	866 8	933 4	1000	1066 8	1133 4	1200	1266 8	1333 4
22×22	403 4	484	564 8	645 4	726	806 8	887 4	968	1048 8	1129 4	1210	1290 8	1371 4	1452	1532 8	1613 4
24×24	480	576	672	768	864	960	1056	1152	1248	1344	1440	1536	1632	1728	1824	1920

FIGURES TO USE ON THE SQUARE FOR RIGHT-ANGLE HOPPERS WITH MITRE-JOINTS.

Slope of Sides of Hopper.	Face Cut.	Edge Cut.	Slope of Sides of Hopper.	Face Cut.	Edge Cut.
	*	*		*	*
2 in 12	11¾ × 12	2 × 12	11 in 12	8⅞ × 12	8⅛ × 12
3 " 12	11⅝ × 12	2⅞ × 12	12 " 12	8½ × 12	8½ × 12
4 " 12	11⅗ × 12	3¾ × 12	13 " 12	8⅛ × 12	8⅞ × 12
5 " 12	11 × 12	4⅝ × 12	14 " 12	7¾ × 12	9⅛ × 12
6 " 12	10¾ × 12	5⅜ × 12	15 " 12	7½ × 12	9⅜ × 12
7 " 12	10¼ × 12	6 × 12	16 " 12	7¼ × 12	9⅝ × 12
8 " 12	10 × 12	6⅝ × 12	17 " 12	7 × 12	9⅞ × 12
9 " 12	9⅗ × 12	7¼ × 12	18 " 12	6¾ × 12	10 × 12
10 " 12	9¼ × 12	7¾ × 12			

* Side of square to use for cut.

FIGURES TO USE ON THE SQUARE FOR RIGHT-ANGLE HOPPERS WITH BUTT-JOINTS.

Slope of Sides of Hopper.	Face Cut.	Edge Cut.	Slope of Sides of Hopper.	Face Cut.	Edge Cut.
	*	*		*	*
8 in 12	10 × 12	14¾ × 12	17 in 12	7 × 12	5 × 12
9 " 12	9⅝ × 12	12¾ × 12	18 " 12	6¾ × 12	4½ × 12
10 " 12	9¼ × 12	11⅛ × 12	19 " 12	6½ × 12	4 × 12
11 " 12	8⅞ × 12	9¾ × 12	20 " 12	6¼ × 12	3⅝ × 12
12 " 12	8½ × 12	8½ × 12	21 " 12	6 × 12	3⅜ × 12
13 " 12	8⅛ × 12	7⅝ × 12	22 " 12	5¾ × 12	3⅛ × 12
14 " 12	7¾ × 12	6¾ × 12	23 " 12	5⅝ × 12	3 × 12
15 " 12	7½ × 12	6⅛ × 12	24 " 12	5½ × 12	2⅞ × 12
16 " 12	7¼ × 12	5½ × 12			

* Side of square to use for cut.

To Find the Rise and Tread for Stairs.—A good rule for the height of the rise and width of tread of stairs is: Twice the rise plus the tread in inches should equal from 23 to 25 inches, or subtract the sum of two risers from 24 inches, and the remainder will be the width of the tread

The following table shows how many treads or risers there will be in any given distance. The dimensions of the rise or treads are given at the top of the table, and the number to the various distances are given at each side column of the table.

TABLE OF TREADS AND RISES.

Number of Treads.	6-in. Rise, Ft. In.	6¼-in. Rise, Ft. In.	6½-in. Rise, Ft. In.	6¾-in. Rise, Ft. In.	7-in. Rise, Ft. In.	7⅛-in. Rise, Ft. In.	7¼-in. Rise, Ft. In.	7⅜-in. Rise, Ft. In.
1	6	6¼	6½	6¾	7	7⅛	7¼	7⅜
2	1 0	1 0½	1 1	1 1½	1 2	1 2¼	1 2½	1 2¾
3	1 6	1 6¾	1 7½	1 8¼	1 9	1 9⅜	1 9¾	1 10⅛
4	2 0	2 1	2 2	2 3	2 4	2 4½	2 5	2 5½
5	2 6	2 7¼	2 8½	2 9¾	2 11	2 11⅝	3 0¼	3 0⅞
6	3 0	3 1½	3 3	3 4½	3 6	3 6¾	3 7½	3 8¼
7	3 6	3 7¾	3 9½	3 11¼	4 1	4 1⅞	4 2¾	4 3⅝
8	4 0	4 2	4 4	4 6	4 8	4 9	4 10	4 11
9	4 6	4 8¼	4 10½	5 0¾	5 3	5 4⅛	5 5¼	5 6⅜
10	5 0	5 2½	5 5	5 7½	5 10	5 11¼	6 0½	6 1¾
11	5 6	5 8¾	5 11½	6 2¼	6 5	6 6⅜	6 7¾	6 9⅛
12	6 0	6 3	6 6	6 9	7 0	7 1½	7 3	7 4½
13	6 6	6 9¼	7 0½	7 3¾	7 7	7 8⅝	7 10¼	7 11⅞
14	7 0	7 3½	7 7	7 10½	8 2	8 3¾	8 5½	8 7¼
15	7 6	7 9¾	8 1½	8 5¼	8 9	8 10⅞	9 0¾	9 2⅝
16	8 0	8 4	8 8	9 0	9 4	9 6	9 8	9 10
17	8 6	8 10¼	9 2½	9 6¾	9 11	10 1⅛	10 3¼	10 5⅜
18	9 0	9 4½	9 9	10 1½	10 6	10 8¼	10 10½	11 0¾
19	9 6	9 10¾	10 3½	10 8¼	11 1	11 3⅜	11 5¾	11 8⅛
20	10 0	10 5	10 10	11 3	11 8	11 10½	12 1	12 3½
21	10 6	10 11¼	11 4½	11 9¾	12 3	12 5⅝	12 8¼	12 10⅞
22	11 0	11 5½	11 11	12 4½	12 10	13 0¾	13 3½	13 6¼
23	11 6	11 11¾	12 5½	12 11¼	13 5	13 7⅞	13 10¾	14 1⅝
24	12 0	12 6	13 0	13 6	14 0	14 3	14 6	14 9
25	12 6	13 0¼	13 6½	14 0¾	14 7	14 10⅛	15 1¼	15 4⅜
26	13 0	13 6½	14 1	14 7½	15 2	15 5¼	15 8½	15 11¾
27	13 6	14 0¾	14 7½	15 2¼	15 9	16 0⅜	16 3¾	16 7⅛
28	14 0	14 7	15 2	15 9	16 4	16 7½	16 11	17 2½
29	14 6	15 1¼	15 8½	16 3¾	16 11	17 2⅝	17 6¼	17 9⅞
30	15 0	15 7½	16 3	16 10½	17 6	17 9¾	18 1½	18 5¼

Number of Treads.	7½-in. Rise, Ft. In.	7⅝-in. Rise, Ft. In.	7¾-in. Rise, Ft. In.	7⅞-in. Rise, Ft. In.	8-in. Rise, Ft. In.	8¼-in. Rise, Ft. In.	8½-in. Rise, Ft. In.
1	7½	7⅝	7¾	7⅞	8	8¼	8½
2	1 3	1 3¼	1 3½	1 3¾	1 4	1 4½	1 5
3	1 10½	1 10⅞	1 11¼	1 11⅝	2 0	2 0¾	2 1½
4	2 6	2 6½	2 7	2 7½	2 8	2 9	2 10
5	3 1½	3 2⅛	3 2¾	3 3⅜	3 4	3 5¼	3 6½
6	3 9	3 9¾	3 10½	3 11¼	4 0	4 1½	4 3
7	4 4½	4 5⅜	4 6¼	4 7⅛	4 8	4 9¾	4 11½
8	5 0	5 1	5 2	5 3	5 4	5 6	5 8
9	5 7½	5 8⅝	5 9¾	5 10⅞	6 0	6 2¼	6 4½
10	6 3	6 4¼	6 5½	6 6¾	6 8	6 10½	7 1
11	6 10½	6 11⅞	7 1¼	7 2⅝	7 4	7 6¾	7 9½
12	7 6	7 7½	7 9	7 10½	8 0	8 3	8 6
13	8 1½	8 3⅛	8 4¾	8 6⅜	8 8	8 11¼	9 2½
14	8 9	8 10¾	9 0½	9 2¼	9 4	9 7½	9 11
15	9 4½	9 6⅜	9 8¼	9 10⅛	10 0	10 3¾	10 7½

TABLE OF TREADS AND RISES—(*Continued*).

Number of Treads.	7½-in. Rise,		7⅝-in. Rise,		7¾-in. Rise,		7⅞-in. Rise,		8-in. Rise,		8¼-in. Rise,		8½-in. Rise,	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
16	10	0	10	2	10	4	10	6	10	8	11	0	11	4
17	10	7½	10	9⅝	10	11¾	11	1⅞	11	4	11	8¼	12	0½
18	11	3	11	5¼	11	7½	11	9¾	12	0	12	4½	12	9
19	11	10½	12	0⅞	12	3¼	12	5⅝	12	8	13	0¾	13	5½
20	12	6	12	8½	12	11	13	1½	13	4	13	9	14	2
21	13	1½	13	4⅛	13	6¾	13	9⅜	14	0	14	5¼	14	10½
22	13	9	13	11¾	14	2½	14	5¼	14	8	15	1½	15	7
23	14	4½	14	7⅜	14	10¼	15	1⅛	15	4	15	9¾	16	3½
24	15	0	15	3	15	6	15	9	16	0	16	6	17	0
25	15	7½	15	10⅝	16	1¾	16	4⅞	16	8	17	2¼	17	8½
26	16	3	16	6¼	16	9½	17	0¾	17	4	17	10½	18	5
27	16	10½	17	1⅞	17	5¼	17	8⅝	18	0	18	6¾	19	1½
28	17	6	17	9½	18	1	18	4½	18	8	19	3	19	10
29	18	1½	18	5⅛	18	8¾	19	0⅜	19	4	19	11¼	20	6½
30	18	9	19	0¾	19	4½	19	8¼	20	0	20	7½	21	3

Number of Treads.	9-in. Rise,		9½-in. Rise,		10-in. Rise,		10½-in. Rise,		11-in. Rise,		13-in. Rise,		14-in. Rise,	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
1		9		9½		10		10½		11	1	1	1	2
2	1	6	1	7	1	8	1	9	1	10	2	2	2	4
3	2	3	2	4½	2	6	2	7½	2	9	3	3	3	6
4	3	0	3	2	3	4	3	6	3	8	4	4	4	8
5	3	9	3	11½	4	2	4	4½	4	7	5	5	5	10
6	4	6	4	9	5	0	5	3	5	6	6	6	7	0
7	5	3	5	6½	5	10	6	1½	6	5	7	7	8	2
8	6	0	6	4	6	8	7	0	7	4	8	8	9	4
9	6	9	7	1½	7	6	7	10½	8	3	9	9	10	6
10	7	6	7	11	8	4	8	9	9	2	10	10	11	8
11	8	3	8	8½	9	2	9	7½	10	1	11	11	12	10
12	9	0	9	6	10	0	10	6	11	0	13	0	14	0
13	9	9	10	3½	10	10	11	4½	11	11	14	1	15	2
14	10	6	11	1	11	8	12	3	12	10	15	2	16	4
15	11	3	11	10½	12	6	13	1½	13	9	16	3	17	6
16	12	0	12	8	13	4	14	0	14	8	17	4	18	8
17	12	9	13	5½	14	2	14	10½	15	7	18	5	19	10
18	13	6	14	3	15	0	15	9	16	6	19	6	21	0
19	14	3	15	0½	15	10	16	7½	17	5	20	7	22	2
20	15	0	15	10	16	8	17	6	18	4	21	8	23	4
21	15	9	16	7½	17	6	18	4½	19	3	22	9	24	6
22	16	6	17	5	18	4	19	3	20	2	23	10	25	8
23	17	3	18	2½	19	2	20	1½	21	1	24	11	26	10
24	18	0	19	0	20	0	21	0	22	0	26	0	28	0
25	18	9	19	9½	20	10	21	10½	22	11	27	1	29	2
26	19	6	20	7	21	8	22	9	23	10	28	2	30	4
27	20	3	21	4½	22	6	23	7½	24	9	29	3	31	6
28	21	0	22	2	23	4	24	6	25	8	30	4	32	8
29	21	9	22	11½	24	2	25	4½	26	7	31	5	33	10
30	22	6	23	9	25	0	26	3	27	6	32	6	35	0

LENGTH, DIAMETER, ETC., OF SPIKES, NAILS, TACKS, ETC.

SPIKES AND NAILS.

Standard Steel Wire Nails.						Steel Wire Spikes.			Common Iron Nails.		
		Common.		Finishing.							
Sizes.	Length, Inches.	Diameter, Inches.	Number per Lb.	Diameter, Inches.	Number per Lb.	Length, Inches.	Diameter, Inches.	Number per Lb.	Sizes.	Length, Inches.	Number per Lb.
2d	1	0524	1060	.0453	1558	3	.1620	41	2d	1	800
3d	1¼	.0588	640	.0508	913	3½	.1819	30	3d	1¼	400
4d	1½	.0720	380	.0508	761	4	.2043	23	4d	1½	300
5d	1¾	.0764	275	.0571	500	4½	.2294	17	5d	1¾	200
6d	2	.0808	210	.0641	350	5	.2576	13	6d	2	150
7d	2¼	.0858	160	.0641	315	5½	.2893	11	7d	2¼	120
8d	2½	.0935	115	.0720	214	6	.2893	10	8d	2½	85
9d	2¾	.0963	93	.0720	195	6½	.2249	7½	9d	2¾	75
10d	3	.1082	77	.0808	137	7	.2249	7	10d	3	60
12d	3¼	.1144	60	.0808	127	8	.3648	5	12d	3¼	50
16d	3½	.1285	48	.0907	90	9	.3648	4½	16d	3½	40
20d	4	.1620	31	.1019	62	.....	.....	.....	20d	4	20
30d	4½	.1819	22	.....	.....	.....	.....	.....	30d	4½	16
40d	5	.2043	17	.....	.....	.....	.....	.....	40d	5	14
50d	5½	.2294	13	.....	.....	.....	.....	.....	50d	5½	11
60d	6	.2576	11	.....	.....	.....	.....	.....	60d	6	8

TACKS.

Title, Ounce.	Length, Inches.	Number per Pound.	Title, Ounce.	Length, Inches.	Number per Pound.	Title, Ounce.	Length, Inches.	Number per Pound.
1	⅛	16,000	4	7/16	4000	14	13/16	1143
1½	3/16	10,666	6	9/16	2666	16	⅞	1000
2	¼	8,000	8	⅝	2000	18	15/16	888
2½	5/16	6,400	10	11/16	1600	20	1	800
3	⅜	5,333	12	¾	1333	22	1 1/16	727
						24	1⅛	666

NUMBER AND DIAMETER OF WOOD SCREWS.

Number.	Diameter.	Number.	Diameter.	Number.	Diameter.	Number.	Diameter.
0	.056	8	.162	16	.268	24	.374
1	.069	9	.175	17	.281	25	.387
2	.082	10	.188	18	.293	26	.401
3	.096	11	.201	19	.308	27	.414
4	.109	12	.215	20	.321	28	.427
5	.122	13	.228	21	.334	29	.440
6	.135	14	.241	22	.347	30	.453
7	.149	15	.255	23	.361		

WROUGHT SPIKES.

Number to a keg of 150 pounds.

L'gth, Ins.	¼ In., Number.	5/16 In., Number.	⅜ In., Number.	L'gth, Ins.	¼ In., Number.	5/16 In., Number.	⅜ In., Number.	7/16 In., Number.	½ In., Number.
3	2250	....	....	7	1161	662	482	445	306
3½	1890	1208	....	8	....	635	455	384	256
4	1650	1135	....	9	....	573	424	300	240
4½	1464	1064	....	10	....	....	391	270	222
5	1380	930	742	11	....	....	....	249	203
6	1292	868	570	12	....	....	....	236	180

WEIGHT OF COPPER NAILS.

Cut Copper Slating Nails.

1¼ inch, about 190 to the pound.

1½ inch, about 135 to the pound.

Cut Yellow Metal Slating Nails.

1¼ inch, about 154 to the pound.

1½ inch, about 140 to the pound.

Copper Wire Slating Nails.

⅞	inch	No.	12	gauge	about	303	per pound.
1	"	"	12	"	"	270	" "
1¼	"	"	11	"	"	196	" "
1½	"	"	10	"	"	134	" "
1¼	"	"	12	"	"	231	" "
1½	"	"	12	"	"	210	" "

NUMBER OF BOAT SPIKES TO 200-POUND KEG.

Length, Inches.	Diameter.						
	¼ Inch Square.	5/16 Inch Square.	⅜ Inch Square.	7/16 Inch Square.	½ Inch Square.	⅝ Inch Square.	¾ Inch Square.
3	3300	....	....	....	....	....	....
3½	2880	....	....	....	....	....	....
4	2343	1671	....	....	....	....	....
4½	2200	1364	1039	....	....	....	....
5	2030	1308	935	....	....	....	....
5½	1828	1175	880	....	....	....	....
6	1624	1115	710	562	433	....	....
7	1420	988	665	516	400	....	....
8	1220	849	602	453	337	....	....
9	....	....	519	409	305	....	....
10	....	....	468	369	297	182	....
12	....	....	410	302	241	155	....
14	....	....	....	....	216	130	95
16	....	....	....	....	182	122	80

TABLE GIVING AREA OF CIRCLES (IN SQUARE FEET).

D......	0 in.	1 in.	2 in.	3 in.	4 in.	5 in.
Ft.						
1.	.7854	.922	1.07	1.23	1.40	1.58
2.	3 14	3.41	3.69	3.98	4.28	4.59
3.	7 07	7.47	7.88	8.30	8.73	9.17
4.	12.58	13.10	13.64	14.19	14.75	15.32
5.	19.64	20.39	20 97	21.65	22 34	23.04
6.	28.27	29.06	29 87	30.68	31.50	32.34
7.	38.48	39.41	40 34	41.28	42.24	43 20
8.	50 27	51.32	52 37	53.46	54.54	55 64
9	63.62	64.80	66.00	67.20	68.42	69.64
10.	78.54	79.85	81.18	82.52	83.86	85.22
11.	95.03	96.48	97.93	99.40	100.88	102.37
12.	113.10	114.67	116.26	117.86	119.47	121.09
13.	132.73	134.44	136.16	137.89	139.63	141.38
14.	153.94	155.78	157.63	159.49	161.36	163.24
15	176.72	178.68	180.66	182.65	184.66	186.67
16.	201.06	203.16	205.27	207.39	209.53	211.67
17	226.98	229.21	231.45	233.71	235.97	238.24
18.	254.47	256.83	259.20	261.59	263.98	266.39
19	283.53	286.06	288.52	291.04	293.56	296.11
20.	314.16	316.78	319.42	322.06	324.72	327.39

D......	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
Ft.						
1.	1.77	1.97	2 18	2.41	2 64	2 89
2.	4.91	5.24	5.59	5.94	6.30	6.68
3.	9.62	10.08	10.56	11.04	11.54	12.05
4.	15.90	16.50	17.10	17.72	18.35	18.99
5.	23.76	24.48	25.22	25.97	26.73	27 49
6	33.18	34.04	34.91	35.78	36.67	37.57
7.	44.18	45 17	46.16	47.17	48.19	49.22
8.	56.75	57.86	58 99	60.13	61.28	62.44
9.	70.88	72.13	73.39	74.66	75.94	77 24
10	86.59	87.97	89.36	90.76	92.17	93.60
11.	103.87	105.38	106.90	108.43	109.98	111.53
12.	122.72	124.36	126.01	127.68	129.35	131.04
13.	143.14	144.91	146.69	148.49	150.29	152.11
14.	165.13	167.03	168.95	170.87	172.81	174.76
15	188.69	190.73	192.77	194.83	196.89	198.97
16	213.83	215.99	218.17	220.35	222.55	224.76
17.	240.53	242.82	245.13	247.45	249.78	252.12
18.	268.80	271.23	273.67	276 12	278.58	281.05
19	298.64	301.21	303.77	306.36	308.94	311.55
20.	330.06	332.75	335.45	338.16	340.88	343.62

NUMBER OF GALLONS IN ROUND CISTERNS AND TANKS.

Depth in Feet.	Diameter in Feet.							
	5	6	7	8	9	10	11	12
5	735	1,060	1,440	1,875	2,380	2,925	3,550	4,237
6	881	1,270	1,728	2,250	2,855	3,510	4,260	5,084
7	1,028	1,480	2,016	2,625	3,330	4,095	4,970	5,931
8	1,175	1,690	2,304	3,000	3,805	4,680	5,680	6,778
9	1,322	1,900	2,592	3,375	4,280	5,265	6,390	7,625
10	1,469	2,110	2,880	3,750	4,755	5,850	7,100	8,472
11	1,616	2,320	3,168	4,125	5,250	6,435	7,810	9,319
12	1,762	2,530	3,456	4,500	5,705	7,020	8,520	10,166
13	1,909	2,740	3,744	4,875	6,180	7,605	9,230	11,013
14	2,056	2,950	4,032	5,250	6,655	8,190	9,940	11,860
15	2,203	3,160	4,320	5,625	7,130	8,775	10,650	12,707
16	2,356	3,370	4,608	6,000	7,605	9,360	11,360	13,554
17	2,497	3,580	4,896	6,375	8,080	9,945	12,070	14,401
18	2,644	3,790	5,184	6,750	8,535	10,530	12,780	15,248
19	2,791	4,000	5,472	7,125	9,010	11,115	13,490	16,095
20	2,938	4,210	5,760	7,500	9,490	11,700	14,200	16,942

Depth in Feet.	Diameter in Feet.							
	13	14	15	16	18	20	22	24
5	4,960	5,765	6,698	7,520	9,516	11,750	14,215	16,918
6	5,952	6,918	8,038	9,024	11,419	14,100	17,059	20,302
7	6,944	8,071	9,378	10,523	13,322	16,450	19,902	23,680
8	7,936	9,224	10,718	12,032	15,225	18,800	22,745	27,070
9	8,928	10,377	12,058	13,536	17,128	21,150	25,588	30,454
10	9,920	11,530	13,398	15,040	19,031	23,500	28,431	33,838
11	10,913	12,683	14,738	16,544	20,934	25,850	31,274	37,222
12	11,904	13,836	16,078	18.048	22,837	28,200	34,117	40,606
13	12,896	14,989	17,418	19,552	24,740	30,550	36,960	43,990
14	13,888	16,142	18,758	21,056	26,643	32,900	39,803	47,374
15	14,880	17,295	20,098	22,260	28,546	35,250	42,646	50,758
16	15,872	18,448	21,438	26,064	30,449	37,600	45,489	54,142
17	16,864	19,601	22,778	25,568	32,352	39,950	48,332	57,520
18	17,856	20.754	24,118	27,072	34,255	42,300	51,175	60,910
19	18,848	21,907	25,458	28,576	36,158	44,650	54,018	64,294
20	19,840	23,060	26,798	30,080	38,062	47,000	56,861	67,678

To find the number of gallons in a tank of unequal diameter multiply the inside bottom diameter in inches by the inside top diameter in inches, then this product by 34: point off four figures and the result will be the average number of gallons to one inch in depth of the tank.

NUMBER OF U. S. GALLONS IN RECTANGULAR TANKS.

FOR ONE FOOT IN DEPTH.

Width in Feet.	Length of Tank in Feet.										
	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7
2	29.92	37.40	44.88	52.36	59.84	67.32	74.81	82.29	89.77	97.25	104.73
2.5	.....	46.75	56.10	65.45	74.80	84.16	93.51	102.86	112.21	121.56	130.91
3	.....	.....	67.32	78.54	89.77	100.99	112.21	123.43	134.65	145.87	157.09
3.5	.....	.....	.....	91.64	104.73	117.82	130.91	144.00	157.09	170.13	183.27
4	.....	.....	.....	.....	119.69	134.65	149.61	164.57	179.53	194.49	209.45
4.5	.....	.....	.....	.....	.....	151.48	168.31	185.14	201.97	218.80	235.63
5	.....	.....	.....	.....	.....	.....	187.01	205.71	224.41	243.11	261.82
5.5	.....	.....	.....	.....	.....	.....	.....	226.28	246.86	2[illegible]7.43	288.00
6	.....	.....	.....	.....	.....	.....	.....	.....	269.30	291.74	314.18
6.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	316.05	340.36
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	366.54

Width in Feet.	Length of Tank in Feet.									
	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12
2	112.21	119.69	127.17	134.65	142.13	149.61	157.09	164.57	172.05	179.53
2.5	140.26	149.61	158.96	168.31	177.66	187.01	196.3	205.71	215.06	224.41
3	168.31	179.53	190.75	202.97	213.19	224.41	235.[illegible]3	246.8[illegible]	25[illegible]07	269.30
3.5	196.36	209.45	222.54	235.63	248.73	261.82	274.[illegible]0	288.00	301.09	314.18
4	224.41	239.37	254.34	269.30	284.26	299.22	31[illegible].1[illegible]	329.14	344.10	359.06
4.5	252.47	269.30	286.13	302.96	319.79	336.62	353.45	370.28	387.11	403.94
5	280.52	299.22	317.92	336.62	355.32	374.03	392.72	41[illegible].4[illegible]	430.13	448.83
5.5	308.57	329.14	349.71	370.28	390.85	411.43	432.[illegible]0	452.57	47[illegible].14	493.71
6	336.62	359.06	381.50	403.94	426.39	448.83	471.27	49[illegible].71	516.15	538.59
6.5	364.67	388.98	413.30	437.60	461.92	486.23	[illegible]10.54	534.85	559.16	583.47
7	392.72	418.91	445.09	471.27	497.45	52[illegible].64	549.81	575.99	602.18	628.36
7.5	420.78	448.83	476.88	504.93	532.98	5[illegible]1.04	589.08	617.14	645.19	673.24
8	.....	478.75	508.67	538.59	568.51	598.44	62[illegible].36	658.28	688.20	718.12
8.5	.....	.....	540.46	572.25	604.05	635.84	667.63	699.42	731.21	763.00
9	.....	.....	.....	605.92	639.58	673.25	706.90	740.56	774.23	807.89
9.5	.....	.....	.....	.....	675.11	710.65	746.17	781.71	817.24	852.77
10	.....	.....	.....	.....	.....	748.05	785.45	822.86	860.26	897.66
10.5	.....	.....	.....	.....	.....	.....	824.73	864.00	903.26	942.56
11	.....	.....	.....	.....	.....	.....	.....	905.14	946.27	987.43
11.5	.....	.....	.....	.....	.....	.....	.....	.....	989.29	1032.3
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	1077.2

Example.—To find number of gallons in a rectangular tank that is 7.5 feet by 10 feet, the water being 4 feet deep: Look in extreme left-hand column for **7.5**, and opposite to this in column headed **10** read 561.04, which being multiplied by 4, the depth of water in the tank, gives 2244.2, the number of gallons required.

WEIGHT OF ROUGH GLASS PER SQUARE FOOT.

Thickness, inches...........	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	1
Weight, pounds............	2	$2\frac{1}{2}$	$3\frac{1}{2}$	5	7	$8\frac{1}{2}$	10	$12\frac{1}{2}$

LENGTH OF SIDE OF OCTAGON BAYS, ETC.

Example.—Find the length of the side of an octagon bay which projects 3 feet 7 inches from the square.

In the column length of square projection we find 3, the number of feet, and then follow this line out to column 7, the number of inches, where we find 5.0⅞ or 5 feet ⅞ of an inch, the length of the side of the octagon.

Length of Square Projection.	Inches.											
	0	1	2	3	4	5	6	7	8	9	10	11
1	1 5	1.6⅜	1.7¾	1.9¼	1.10⅝	2.0⅛	2.1½	2.2⅞	2.4⅜	2.5¾	2.7⅛	2.8⅝
2	2 10	2 11⅜	3.0⅞	3.2¼	3.3⅝	3.5⅛	3.6½	3.7⅞	3 9⅜	3.10¾	4.0⅛	4.1⅝
3	4 3	4.4⅜	4.5⅞	4.7¼	4.8⅝	4.10⅛	4.11½	5.0⅞	5.2⅜	5.3¾	5 5⅛	5 6⅝
4	5 8	5 9⅜	5.10⅞	6 0¼	6.1⅝	6.3⅛	6.4½	6.5⅞	6.7⅜	6.8¾	6.10⅛	6.11⅝
5	7 1	7.2⅜	7.3⅞	7.5¼	7.6⅝	7.8⅛	7.9½	7.10⅞	8.0⅜	8.1¾	8.3⅛	8.4⅝
6	8.5⅞	8 7¼	8 8¾	8.10⅛	8.11½	9.1	9 2⅜	9.3¾	9.5¼	9.6⅝	9.8	9.9½
7	9.10⅛	10:0¼	10 1¾	10.3⅛	10.4½	10.6	10 7⅜	10 8¾	10.10¼	10.11⅝	11.1	11 2½
8	11.3⅞	11.5¼	11.6¾	11.8⅛	11.9½	11.11	12.0⅜	12.1¾	12.3¼	12.4⅝	12.6	12 7½
9	12 8⅞	12.10¼	12.11¾	13.1⅛	13.2½	13.4	13.5⅜	13.6¾	13.8¼	13.9⅝	13.11	14.0½
10	14 1¾	14 3⅛	14 4⅝	14 6	14.7⅜	14.8⅞	14.10¼	14.11⅝	15.1⅛	15.2½	15 3⅞	15.5⅜
11	15 6¾	15.8⅛	15.9⅝	15.11	16.0⅜	16.1⅞	16 3¼	16.4⅝	16.6⅛	16.7½	16.8⅞	16 10⅜
12	16 11¾	17.1⅛	17.2⅝	17.4	17.5⅜	17.6⅞	17.8¼	17.9⅝	17.11⅛	18.0½	18.1⅞	18.3⅜
13	18 4¾	18.6⅛	18.7⅝	18.9	18.10⅜	18 11⅞	19.1¼	19 2⅝	19 4⅛	19 5½	19.6⅞	19.8⅜
14	19 9⅝	19.11	20 0½	20.1⅞	20.3¼	20.4¾	20.6⅛	20 7½	20.9	20.10⅜	20.11¾	21.1¼
15	21 2⅝	21 4	21 5½	21 6⅞	21 8¼	21.9¾	21.11⅛	22.0½	22 2	22.3⅜	22.4¾	22 6¼
16	22.7⅝	22.9	22.10½	22.11⅛	23 1¼	23 2¾	23 4⅛	23.5½	23.7	23 8⅜	23 9¾	23 11¼
17	24 0⅝	24.2	24 3½	24.4⅞	24 6¼	24.7¾	24.9⅛	24.10½	25.0	25 1⅜	25 2¾	25.4¼
18	25 5½	25.6⅞	25.8⅜	25.9¾	25.11⅛	26.0⅝	26.2	26 3⅜	26.4⅛	26.6¼	26 7⅝	26 9⅛

HEIGHT OF TALL BUILDINGS, TOWERS, SPIRES, ETC.

Eiffel Tower, France	985 feet
Tower of Babel	680 "
Metropolitan Life Insurance Building	700 "
Singer Building, New York	612 "
Washington Monument, Washington, D. C	555 "
City Hall, Philadelphia, Pa	537 "
Cologne Cathedral, Germany	512 "
Tower of Baalbec	500 "
Rouen Cathedral, France	495 "
Pyramid of Cheops, Egypt	486 "
Antwerp Cathedral, Belgium	476 "
Church of St. Nicholas, Hamburg	473 "
Pyramid of Cephrenes, Egypt	473 "
Strasburg Cathedral, Germany	468 "
St. Martin's, Landshut, Germany	462 "
Vienna Cathedral, Austria	449 "
St. Peter's Church, Rome	448 "
St. Stephen's, Vienna	446 "
Cathedral at Amiens	422 "
St. Mary's, Lubeck, Germany	413 "
Salisbury Cathedral	404 "
Antwerp Cathedral, Belgium	402 "
Palace of Justice, Brussels, Belgium	400 "
Cremona Cathedral	392 "
Park Row Building, New York	392 "
St Peter's, Rome	391 "
Cathedral at Florence, Italy	386 "
Church at Fribourg, Germany	386 "
City Hall, Brussels	370 "
St. Paul's, London	365 "
Cathedral of St. Petersburg	363 "
Times Building, New York	363 "
Cathedral of Seville, Spain	360 "
International Banking Company's Building, New York	352 "
Cathedral of Utrecht, Holland	356 "
Pyramid of Sakkarah, Egypt	356 "
Cathedral of Milan, Lombardy	355 "
Manhattan Life Insurance Building, New York	348 "
Wall St. Exchange Building, N. Y	340 "
Victoria's Tower, House of Parliament, London	340 "

Madison Square Garden Tower, New York	332 feet
St. Mark's Church, Venice, Italy	328 "
St. Paul Building, New York	317 "
Land & Title Building, Philadelphia	317 "
Court House, Pittsburg Pa	319 "
Duomo, or Sta. Maria del Fiore, at Florence	310 "
Pulitzer Building, New York	309 "
American Surety Building, New York	308 "
American Tract Society Building, New York	306 "
Statue of Liberty, New York Harbor	305 "
Masonic Temple, Chicago, Ill	303 "
Lincoln Cathedral, England	300 "
"Flatiron" Building, New York	293 "
Empire Building, New York	293 "
Trinity Building, New York	290 "
Capitol Building, Washington, D. C.	287½ "
Trinity Church	286 "
Assinelli Tower, Bologna, Italy	272 "
Pantheon, Paris	274 "
Auditorium, Chicago	270 "
Bank of Commerce Building, N. Y	264 "
Column at Delhi, Hindoostan	262 "
Porcelain Tower at Nankin, China	262 "
Notre Dame Cathedral, Paris	264 "
State Capitol, Hartford, Conn	256 "
Fischer Building, Chicago	235 "
Bunker Hill Monument, Massachusetts	221 "
New Netherlands Hotel, N. Y	220 "
Cathedral Notre Dame, Montreal, Canada	220 "
Grace Church, New York	216 "
St. John's Church, New York	210 "
St Paul's, New York	200 "
Leaning Tower of Pisa, Italy	188 "
Ames Building, Boston	186 "
Opera House, Paris	183 "
Washington Monument, Baltimore	175 "
July Column, Paris	154 "
Nelson's Monument, Trafalgar Square, London	154 "
Trajan's Pillar, Rome	151 "
State, War, and Navy Building, Washington	145 "
Obelisk of Luxor, Paris	110 "

VARIOUS RECEIPTS AND SHORT CUTS.

Miscellaneous Receipts. — TEST FOR SEWER-GAS. — Saturate unglazed paper with a solution of 1 ounce pure lead acetate in half a pint of rain-water; let it partially dry, then expose in the room suspected of containing sewer-gas.

The presence of gas in any considerable quantity soon darkens or blackens the test-paper A suspected joint of a pipe can be tested by wrapping with a single layer of white muslin, moistened with the above solution, and if gas is escaping it will darken the cloth.

TO CLEAN COPPER.—Take 1 ounce of oxalic acid, 6 ounces of rotten stone, ½ ounce of gum arabic, all in powder, 1 ounce of sweet-oil, and sufficient water to make a paste. Apply a small portion and rub dry with a flannel or leather.

REMOVAL OF STAINS FROM GRANITE.—A paste of 1 ounce of ox-gall, 1 gill of strong solution of caustic soda, 1½ tablespoonfuls of turpentine, with enough pipe-clay to make it thick, and scour well.

Or, mix together ¼ pound soft soap, 1 ounce washing-soda, and a piece of sulphate of soda as big as a walnut. Rub it over the surface proposed to clean, let it stand twenty-four hours, and then wash off; or, smoke and soot stains can be removed with a hard scrubbing-brush and fine sharp sand, to which add a little potash.

Or, use strong lye, or make a hot solution of 3 pounds of common washing-soda dissolved in 1 gallon of water. Lay it on the granite with a paint-brush.

TO CLEAN MARBLE.—Mix 2 parts by weight of sal-soda, 1 part powdered chalk or fine bolted whiting, and 1 part powdered pumice-stone with enough water to make a thin batter, and by the means of a scrubbing-brush apply it to the spots; then wash off with soap and water.

Or, to remove grease spots from marble, moisten fine whiting or fullers' earth with benzine, apply it in a thick layer to the spots, and let it remain for some time; then remove the dry paste and wash the spot with soap and water.

To extract oil stains from marble, make a paste by mixing 2 parts of fullers' earth, 1 part soft soap, and 1 part potash with

boiling water. Apply this paste to the spots and let it remain three or four hours.

To Remove Paint from Window Glass.—Put sufficient saleratus into hot water to make a strong solution, and with this saturate the paint which adheres to the glass. Let it remain until nearly dry, then rub it off with a woollen cloth.

To Make Modelling Clay.—Knead dry clay with glycerine instead of water, work thoroughly with the hands, moisten work at intervals of two or three days, and keep covered to prevent evaporation of moisture.

To Clean Paint.—When paint is washed with any strong alkaline solution, such as soda or strong soap, the oil of the paint is liable to be changed to soap and the paint is seriously injured. To avoid this, take some of the best whiting, and have ready some clean warm water and a piece of flannel, which dip into the water and squeeze nearly dry; then take up as much whiting as will adhere to it, apply it to the painted surface, when a little rubbing will quickly remove any dirt or grease stains. After this wash the part well with clean water, rubbing it dry with a soft chamois. Paint thus cleaned will look as well as when first put on, and the operation may be tried without fear of injury to the most delicate colors. It answers far better than the use of soap, and does not require more than one-half the time and labor. Another simple method is the following: Put a tablespoonful of aqua ammonia in a quart of moderately hot water, dip in a flannel cloth, and with this merely wipe over the surface of the woodwork. No rubbing is necessary. The first recipe is preferable, except where the paint is badly discolored.

To Age or Color Copper.—Add about 1 pound of powdered sal ammoniac to 5 gallons of water, dissolve it thoroughly, and let it stand at least twenty-four hours before putting it on the copper. Apply it to the copper with a brush, being sure to cover every place; let it stand for a day and sprinkle with water, using a brush to sprinkle the water on so that it will not run and streak the copper. After standing overnight the color will be as desired. The same effect can be produced by using vinegar and salt instead of the sal ammoniac, using ½ pound of salt to 2 gallons of vinegar.

To Remove Old Glass from Sash.—Take a hot iron and run along the surface of the putty, when it can easily be removed with a chisel.

To Remove Rust Stains.—To remove rust stains from wood wash the disfigured parts with a solution of 2 ounces of oxalic acid to 1 pint of hot water.

In fitting doors always keep the hollow side next the stop or rebate strip.

When hanging transoms, where possible, if the transom is to be hung at the top, hang them so that when they are open the glass will lay on the wood and not on the putty.

Wash-stands are usually set 2 feet 6 inches from the floor.

The relative strength of timbers is estimated by multiplying the breadth by the square of the depth.

Example.—How many times as strong is a joist $2\frac{1}{2}'' \times 15''$ when supported on its narrow side as when supported on its broad side? $2\frac{1}{2} \times 2\frac{1}{2} = 6\frac{1}{4}$, $6\frac{1}{4} \times 15 = 93\frac{7}{10}$, $15 \times 15 = 225$, $225 \times 2\frac{1}{2} = 562\frac{1}{2}$, $562\frac{1}{2} \div 93\frac{7}{10} = 6$, or six times stronger.

Bevel of Doors.—In fitting doors the lock-edge should be given a bevel of $\frac{1}{8}$ inch in $2\frac{1}{4}$ inches, as this is the standard bevel given the face of locks. If the door be narrow it may be necessary to give it a little more bevel than this in order to clear the jamb as the door opens.

Astragal of Sliding-doors.—The standard astragal-joint of sliding-doors has a $\frac{3}{4}$-inch half-round or bead, with a groove to receive it slightly larger to give a little play.

Height of Chairs, etc.—The height of a chair-seat above the floor is 18 inches. The height of a table above the floor is 2 feet 5 inches.

Size of Bedsteads.—A single bed is 3 to 4 feet wide. A three-quarter bed is 4 to 4 feet 6 inches wide. A double bed is 5 feet wide. All bedsteads are from 6 feet 6 inches to 6 feet 8 inches long.

Size of Pianos.—Upright pianos vary in size from 4 feet 8 inches to 5 feet 8 inches long, and from 2 feet 2 inches to 2 feet 8 inches in depth.

Size of Bowling-alley.—A regulation bowling-alley is 65 feet long, $3\frac{1}{2}$ feet wide, with an additional 10 feet of floor-space.

Size of Billiard-tables.—Billiard-tables are 4 feet by 8 feet, 4 feet 2 inches by 9 feet, and 5 feet by 10 feet.

Size of Horse-stalls.—Horse-stalls should be made 4 feet or 5 feet or over in width by 9 feet in length. They should never be made between 4 and 5 feet, as the horse is liable to cast himself.

Height of Horse-troughs.—Horse or cattle water-troughs

should be made about 26 inches from floor or ground to the top of the trough.

Height of Hand-rails.—The usual height of hand-rails is about 2 feet 7 inches from the top of the step on line with the ri er of the step.

Height of Base in Rooms.—A good rule for the height of base is to divide the height of the story by 10 and multiply this answer by $\frac{5}{6}$, which will give the height of the base; or make the base the same number of inches in height that the story is in feet.

Height of Chair-rails.—Chair-rails should be about 36 inches from the floor to top of rail. In some cases the height is governed by the height of the window-stools.

Hand or Loose-pin Butts.—A loose-pin butt that will work on a door opening from you to the right, when standing at the opposite side of the partition from that which the door is hung, is a right-hand butt, and a left-hand butt if it will work on a door opening to the left. The same rule applies to locks.

Rope-mouldings.—Rope may be used as spiral mouldings in circular and curved work where wooden mouldings could not be employed without incurring extraordinary expense. The rope should be soaked for a few hours in thin starch and glue, equal parts, thoroughly mixed together.

When the rope is to be nailed in place wipe off all the adhesive matter, then secure one end in place and twist the rope until the strands appear more prominent than ordinarily, then nail in place.

After the rope is secured in place take a pointed stick and draw along the creases of the rope, thus bringing the strands into more prominence. Such mouldings may be finished with wood-filler, painted and varnished. Boiled oil can be used in place of the mixture of starch and glue.

Hand of Stairways.—If, in ascending stairway, the rail is on the right-hand side it is a right-hand stairway. If the rail is on the left-hand side then it is a left-hand stairway.

Spacing Roof-lath for Slate or Shingles.—When a roof is sheathed with lath or strips they should be spaced the same distance, centre to centre, that the slate or shingles are to show to the weather.

Bridging Partitions.—When bridging partitions tack a

stud horizontally across the face of the partition and draw all the studs into line. Then cut in the bridging and nail solid, and it will keep the studs in line. Straight partitions and true plastering can be obtained in this way with a little care.

Height of Wardrobe-shelves. Shelves in wardrobes should be set about 5 feet 10 inches from the floor, when there is to be a cloak-rail under the shelf; the hooks on the cloak-rail should be about 5 feet 6 inches from the floor.

Setting Door-jambs.—The openings for doors should be framed about ¾ inch larger than the outside measurement of the jambs, and in setting the jambs use shingles for wedging. A bunch of shingles on a job when the door-jambs are being set will save many an hours' time.

Nailing Moulding of Doors.—When nailing the moulding in the panels of moulded doors care should be taken not to drive any nails so that they will come in the way of the bit when boring for the mortise of the lock. Many a bit has been spoiled and many an hours' time lost by nails driven where the mortise for the lock is to be cut. In some cases it is well to tack the piece of moulding at this point, leaving it to be nailed fast after the lock is cut in.

Cement for Stopping Flaws in Wood.—Put any quantity of fine sawdust of the same wood your work is made with into an earthen pan, and pour boiling water on it; stir it well, and let it remain for a week or ten days, occasionally stirring it. Then boil it for some time, and it will be of the consistency of pulp or paste. Put it into a coarse cloth and squeeze all the moisture from it. Keep for use, and, when wanted, mix a sufficient quantity of thin glue to make a paste; rub it well into the cracks, or fill up the holes in your work with it. When quite hard and dry clean your work off, and, if carefully done, you will scarcely discern the imperfection.

Nailing Base and Moulding at Mantels.—In making a return of the base and moulding at a mantel never nail the base or moulding fast to the mantel. The mantel should be left free to be taken off the hooks at any time.

To Bend Mouldings.—To bend a moulding around a circle rip the moulding into strips, each strip being a member of the moulding, so the joints will come at the intersections of the members; then each strip can be bent separately.

To Fit Doors.—In fitting doors a good rule is to make the

space between the door and jamb just large enough so a silver quarter will slide around the door; this will give sufficient space for the paint or varnish and for the door to work easily. Always fit the door so that the hollow side lays against the stop or rebate.

Driving Nails Under Water.—To drive nails under water take a piece of pipe long enough to set on the timber, or whatever it is the nail is to be driven into; place it on the timber and drop the nail into it point first, then drop an iron rod down on top of the nail, and use the hammer on top of the rod to drive the nail.

Soundness of Timber.—The soundness of timber may be ascertained by placing the ear close to one end of the timber while another person strikes a succession of blows on the opposite end, using a hammer or mallet. If the stick is sound the blows of the hammer will sound clear, but if they sound dull it indicates an unsound place in the timber.

Corner-blocks.—When putting up block-trim always set the corner-blocks so the grain will stand vertical, the end wood will then not show at the side.

Side of an Octagon.—To find the length of one side of an octagon when the short diameter is given multiply this diameter by 0.4141.

Radius of Door- or Window-openings.—The radius of a segment, door, or window head should be equal to the width of the opening.

To Cut a Stick Square or on an Angle of 45° without a Square.—Place the saw on the stick in a position to saw, and note the reflection of the stick on the side of the saw. If the reflection and the stick are in a line, then the saw is in a position to make a square cut. If the reflection and the stick are at right angles, then the saw is in position for a square mitre or angle of 45°.

To Find the Power of a Lever.—*Rule.*—As the distance between the weight and the fulcrum is to the distance between the power and the fulcrum so is the power to the weight.

To Find the Power of Pulleys or Set of Blocks.—*Rule.*—As one is to twice the number of movable pulleys so is the power to the weight.

Size of Gutters and Down-spouts or Conductor-pipes.—A rule of the American Bridge Company requires the following sizes for gutters and conductor-pipes:

Size of Roof.	Gutter.	Conductor.
Up to 50 feet.........	6 inches........	4 inches every 40 feet
50 " 70 ".........	7 "	5 " " 40 "
70 " 100 ".........	8 "	5 " " 40 "

Paste for Paper to Iron. For pasting paper to iron or steel mix dextrine with water and boil it down until it assumes about the consistency of very thin glue; it will not hold on greasy or oily substances.

Ink for Zinc.—An ink which can be used with a drawing-pen on zinc and which is acid-proof is made of 1 dram verdigris, 1 dram sal-ammoniac powder, and ½ dram lampblack, mixed with 10 drams of water.

Oil for Oil-stones.—A good oil for oil-stones is made by mixing equal parts of sperm- and carbon-oil (coal-oil).

Nailing in Hardwoods. — When working in hardwoods bore a hole in the end of the hammer-handle and fill with soap or beeswax. When a nail is to be driven place the point of it in the beeswax or soap and it will drive much easier.

Penny as Applied to Nails.—The term " penny " is derived from pound. It originally meant so many pounds to the thousand. Threepenny nails would mean three pounds to the thousand nails; eightpenny nails, eight pounds to the thousand nails, etc.

To Mark Tools, etc.—Take 7 ounces of nitric acid and 1 ounce of muriatic acid; mix, and shake together, then cover the tool where it is desired to mark with beeswax, and take a needle or other sharp instrument and scratch the name plainly in the beeswax; then apply the acid with a feather, filling up the scratch in the wax; let it remain for about five minutes, then wash off with water and rub with oil.

To Adjust a Level.—Place the level against a wall or some solid place, and in position so that the bead in the glass is at the centre and mark the position of both ends of the level on the wall; now reverse the level; place one end to one of the marks made, and move the other end until the bead is in the centre again and mark the second position; now divide the space between the two marks made and place the end of the level to this mark, and turn the adjusting-screw of the level until it brings the bead to the centre, when the level will be true.

Improved Marking-gauge.—An improvement is made on the ordinary marking-gauge by boring a hole in one end and splitting the gauge so that a lead-pencil can be inserted and held. If there is not spring enough in the wood to hold the pencil put in a small screw to clamp the two sides together and hold the pencil.

To Fit Keys.—To fit a key in a lock when the lock cannot be taken out hold the key over a flame until it is well smoked; then place carefully in the lock and turn it as far as possible; then take out, and where it strikes and needs filing will be marked in the soot.

Resilience of Timber.—Comparative resilience of various kinds of timbers: ash being 1; fir, 4; elm, 54; pitch-pine, 57; teak, 59; oak, 63; spruce, 64; yellow pine, 64; cedar, 66; chestnut, 73; larch, 84; beech, 86. (By resilience is understood the quality of springing back or toughness.)

Increase of Strength of Timber by Seasoning.—Percentage of increase, strength of different woods by seasoning: white pine, 9%; elm, 12.3%; oak, 26.6%; ash, 44.7%; beech, 61.9%.

Trestles, Step-ladders, etc.—When making trestles, step-ladders, etc. for use during the construction of a building, make the legs 4 feet apart, centre to centre, so they will span, and set securely on the joist, whether spaced 12 or 16 inches on centres.

Size of Dentils.—The size of dentils vary according to the order of architecture in which they are used, but a good rule for proportioning the size of dentils is as follows:

Width $= \frac{7}{12}$ of length;
Thickness $= \frac{7}{12}$ of length;
Space between $= \frac{1}{2}$ of width;

A Good Paint for Roofs or Outbuildings.—Take 1 gallon of crude petroleum and add to it slowly 3 pounds of Prince's Brown Metallic, mix thoroughly, and if necessary thin down with a little coal-oil. Apply in the same manner as ordinary paint.

To File a Saw.—When filing a saw use the file with the point toward the handle of the saw, as this leaves the ragged edge on the back of the tooth and keeps the cutting edge of the tooth sharp.

Size of a Flour-barrel.—A flour-barrel is 28 to 30 inches in height, and 20 to 21 inches in diameter.

To Swing a Door over an Uneven Floor.—To swing a door over an uneven floor, or one that rises where the door swings so that the door rubs, use a wide butt at the bottom and a narrow one at the top of the door. This will raise the front of the door as it is opened. Two sizes of butts can also be used in this manner, to give a little gravity to the door to keep it closed.

Sheathing Paper Back of Frames.—When sheathing paper is used on a building and the siding is to be cut between the casings and the corner-boards always run a strip of the paper under the casings and corner-boards as they are put on; this strip of paper can then be lapped on the paper as it is put on and makes a tight job.

Nailing Bridging.—Do not nail the bottom end of floor bridging until after the floor is laid, as the floor then brings the joist into line.

TABLES CONVENIENT FOR TAKING INSIDE DIMENSIONS.

A box $24 \times 24 \times 14.7$ inches will hold a barrel of $31\frac{1}{2}$ gallons.
A box $15 \times 14 \times 11$ inches will hold 10 gallons.
A box $8\frac{1}{4} \times 7 \times 4$ inches will hold a gallon.
A box $4 \times 4 \times 3.6$ inches will hold a quart.
A box $24 \times 23 \times 16$ inches will hold 5 bushels.
A box $16 \times 12 \times 11.2$ inches will hold a bushel.
A box $12 \times 11.2 \times 8$ inches will hold a half-bushel.
A box $7 \times 6.4 \times 12$ inches will hold a peck.
A box $8.4 \times 8 \times 4$ inches will hold a half-peck, or 4 dry quarts.
A box $6 \times 5\frac{3}{5} \times 4$ inches will hold a half-gallon.
A box $4 \times 4 \times 2\frac{1}{10}$ inches will hold a pint.

Fire-brick.—Fire-brick are made by a similar process to making ordinary brick, but from different material. The clay used is known as fire-clay. This clay is composed of hydrated silicates of alumina, associated with silica and alumina in various states or subdivisions and sufficiently free from alkalies, iron, and lime to resist vitrification at high temperature.

Oxide of iron or sulphate of iron in the clay is very injurious, and when found in the brick in a quantity of more than 5 per cent they should be rejected. Lime, soda, potash, and magnesia are also injurious and any fire-brick containing over 3 per cent of either should be rejected.

Good fire-clay should contain 50 to 80 per cent of silica and 18 to 35 per cent of alumina; it should be of a uniform texture and have a greasy feel between the fingers.

Fire-brick which are to be exposed to heat should be laid in fire-clay, and should be thoroughly wet before laying; the mortar should be used very thin and the joint made as tight as possible.

VITRIFIED BRICK are brick burned to a hard glossy consistency so as to be impermeable to water and fit for damp-proof work, paving, and such purposes.

LAYING FIRE-BRICK.—*Fire-clay.*—Fire-clay is *not a cement*, and it has little or no holding power. Its office is therefore not to act as a binder, but merely to fill the voids. In consequence a fire-brick joint is the more perfect in proportion as the quantity of fire-clay approaches the amount necessary to fill the voids, without preventing the brick from touching, precisely as in case of a glue joint between pieces of wood. Clay of consistency sufficient to permit use of trowel should not be permitted; the proper way is to mix the clay to requisite thinness, dip each brick into the clay, "rub and shove" each brick into final place, then drive it with mallet or hammer and block until it actually touches the brick below it. *Rigid adherence to these directions is absolutely essential when constructing fire-arches.*

The two defects of fire-clay are its shrinkage during drying and its lack of cementing power. The former may be greatly diminished by adding to the clay about 20 per cent of its volume of fire-brick pulverized and sifted to *fire-brick flour*. This can be obtained in many places, but unless it is of the requisite fineness, avoid it, as coarse material will thicken the joints an amount which offsets the advantage.

The cementing power of fire-clay may be increased by adding to and slacking in with it about $1\frac{1}{4}$ per cent of its volume of lime; measure the clay and for each cubic foot put in a piece of lime not exceeding $4'' \times 2'' \times \frac{1}{2}''$. This will have just sufficient fluxing power to unite with the clay and form a hard clinker which takes a grip on the fire-brick. It should always be used when building arches.

After all is done give the joints several coats of clay wash, which should be made of a thin solution of fire-clay and be applied with a whitewash-brush.

From 600 to 800 pounds of fire-clay is enough to lay 1000 brick.

All fire-brick work should be warmed up slowly to expel moisture before applying severe heat.

General Rules for Brick Chimneys or Stacks.—The diameter of the base should not be less than one-tenth of the height if square; if round, one-twelfth of the height.

Batter of chimn ys, 0.03 inch to the foot.

The thickness of the brickwork should be one brick, from top, to 25 feet from same; a brick and a half from 25 to 50 feet from the top, increasing by the half-brick every 25 feet from the top. If the inside diameter at the top exceeds 4 feet 6 inches, the top length should be a brick and a half.

Four courses of brickwork will lay 1 foot in height in a chimney.

In building chimneys from stoves or fireplaces never connect two fires to one flue or neither one may burn satisfactorily; each fire should have a separate flue running to the top of the chimney.

Fireplace Openings in Chimneys.—Fireplace openings for grates should be about 2 feet 5 inches in height from the floor, and about 6 inches larger in width than the size grate to be used so as to allow for the fire-brick lining.

An iron bar $\frac{3}{4}$ inch by 3 inches makes the best arch for over a fireplace. If a brick arch is used it should be a flat jack-arch.

Iron Bond in Brick Walls.—In brick walls where great strength is desired flat iron, say $\frac{3}{16}'' \times 3''$, can be bedded in the walls at certain intervals ruuning lengthwise of the wall.

When the walls of the Palace Hotel, San Francisco, were built, iron bond of this kind was built in the walls to give them strength to withstand the shocks of earthquakes. That it fulfilled the purpose for which it was put in the walls is shown by the fact that the walls of the building were not damaged by the earthquake when this part of the city was destroyed, but the building was destroyed by fire.

Brick for Laying Circle Walls.—Brick for laying circle walls should be made to conform to the desired radius if the circle has a radius of less than 7 feet. Brick to lay a radius of 7 feet or over can be selected from straight brick, as the brick to lay a 7-foot radius has a curve of but $\frac{1}{16}$ inch to a brick.

The curve of brick to lay various circles are as follows:

Brick to work to a radius of 1 foot should have a curve of $\frac{11}{16}$ inch to the brick.

Brick to work to a radius of 1 foot 6 inches should have a curve of $\frac{1}{2}$ inch to the brick.

Brick to work to a radius of 2 feet should have a curve of $\frac{5}{16}$ inch to the brick.

Brick to work to a radius of 2 feet 6 inches should have a curve of $\frac{1}{4}$ inch to the brick.

Brick to work to a radius of from 3 feet to 4 feet should have a curve of $\frac{3}{16}$ inch to the brick.

Brick to work to a radius of from 4 feet to 6 feet should have a curve of $\frac{1}{8}$ inch to the brick.

Brick to work to a radius of from 6 feet to 7 feet should have a curve of $\frac{1}{16}$ inch to the brick.

Lime Mortar in Thick Walls.—Pure lime mortar should not be used in any thick, heavy masonry. Pure lime mortar requires air to cause it to harden or set, and if used in the interior of thick walls is liable to dry out without attaining any strength whatever.

In all thick walls a hydraulic lime or lime and cement mortar should be used.

Masons' Plumb-rule.—The spirit plumb-rule is now generally used by all masons, and is quicker but not so reliable as the old plumb-bob. A spirit plumb-rule should be tested often to see if true; a knock or jar may move the glass a little and make the rule untrue. A good way is for the mason to test his plumb-rule every morning before starting to work.

To test the plumb-rule, hold it up against the side of a house or some solid object and when the "bead" shows plumb scribe a mark on the wall at top and bottom of the rule, now turn the rule over, place the edge of the rule again to the marks, and if the "bead" shows plumb the rule is true, but if not it should be adjusted as explained for adjusting the level on page 194.

To Remove Stains from Stone.—Take fullers' earth and make a paste to which add a little lye; spread this on the stain and let dry, then wash clean. It may require two or three applications to take out the stain.

To Select a Mallet or Hammer-handle.—In selecting a wooden mallet or a hammer-handle, pick out a light-colored one, as this is the sap-wood and is tougher than the dark wood, which comes from the heart of the tree. Tests have shown that the

toughest part of the tree is the sap-wood or part next the bark just above the ground.

Size of Brick to Lay English Cross Bond.—Brick to work English cross bond: the length of the brick must equal twice the width plus the thickness of one mortar joint.

Thus, brick 8″ long to lay English cross bond with $\frac{1}{4}''$ joint must be $3\frac{7}{8}''$ wide.

A New Method for Cleaning Stonework has just been given a practical trial by the Treasury Department. The whole of the Treasury Building has been cleaned for the first time in 40 years. The work was done in 50 days and the change in the appearance of the building from a sooty gray to granite white is as striking as if it had been rebuilt of new stone. The cleaning has been done by the aid of a liquid preparation invented by Mr. James F. Bruce, of Washington, D. C. The ingredients of the liquid are secret, but the inventor has applied for a patent. The liquid is colorless and does not in any way injure the stone. It is applied with an ordinary paint-brush, and this is followed by a wet sponge which seems to gather up the cleaning liquid and the dirt. The work is finished by the application of a hose and the granite appears as clean as if new. The result is said to be as satisfactory as the sand-blast method for granite and other hard stone, though inapplicable to sandstone. It is also much less disagreeable to owners of neighboring property and to passers-by. The chief advantage of the process lies, however, in its extreme cheapness and in the ease and rapidity with which it is applied.

Efflorescence.—When the face of some walls become wet or damp they will be covered with a sort of white efflorescence; it is in some cases a nitrate or carbonate of potash, more frequently a carbonate or sulphate of soda. There is no way to prevent this unless by coating the bricks with some preparation to render them water- and moisture-proof.

Size of a Brick-hod.—A brick-hod measures 8 inches on the sides and 20 to 22 inches in length, and will carry 16 to 20 bricks.

Size of Mortar-hod.—The mortar-hod is usually made about 22 inches in length and 12 to 14 inches deep on the sides.

Stain for Staining Bricks.—For staining bricks red, melt 1 ounce of glue in 1 gallon of water, add a piece of alum the size of an egg, then $\frac{1}{2}$ pound Venetian red and 1 pound of Spanish

brown. Try the color on the bricks before using and change light or dark with the red or brown, using a yellow mineral for buff.

ARTIFICIAL MARBLE.—According to M. Maard, artificial marble may be produced in the following manner: 10 parts of burnt gypsum and 1 part of alum are mixed together in a little water. This is then calcined and afterward reduced to a powder. To 25 parts of the powder is added 22 parts of talc, 5 parts of magnesium chloride, 44 parts of clay, and 1 part of potassic alum. This mixture can be worked polished, or painted similar to marble.

PROTECTION OF STONEWORK.—The stone belt course and all stone trimmings should be carefully protected from the mortar of the brickwork above. This can be done by building in a strip of heavy building paper (not tar paper) under the first course of brick above the stone, letting the paper hang out over the stone so as to shed the mortar droppings. The paper should be let into the joint about 1 inch and can be cut off when the walls are washed down.

TO BRIGHTEN OLD BRICKWORK.—To make brickwork look new and bright apply a wash as follows: Take ½ pound of glue, soak it in water overnight and then dissolve it in about 8 gallons of water, then add 1 ounce of bichromate of potash in solution and 10 pounds of dark Venetian red and enough yellow ochre to give the desired shade. Apply the wash as thin as possible with a large whitewash-brush.

TO CLEAN BRICKWORK.—Mix together 1 pint of liquid ammonia, 1 gallon soft soap, 2 pounds powdered pumice. This will make a soft paste which can be applied with a brush. Dust off the brickwork and apply a coat of the mixture and after letting it stand about twenty minutes scrub it off, using a scrubbing-brush and clean water. Then rinse off with a hose.

IMPRESSION-WAX.—To make squeezing-wax for taking reverse impressions of carvings, mouldings, or other work, take 9 ounces of beeswax, 12 ounces lard, 3 ounces olive-oil, and 5 pounds whiting (or in like proportion). Melt the three former ingredients together, then add the whiting, pounding it up well before mixing. When cold knead well together with the hands; or, take ½ pound of hogs' lard, ½ pound of beeswax, 2 pounds of flour, 1 gill of linseed-oil; melt all down. If too sticky add more flour; if too hard melt down again and add a little more lard.

GELATINE MOULDS FOR PLASTER CASTING.—To prepare gelatine for making moulds, take 4 parts by weight of gelatine and let soak in water for several hours until it has absorbed all the water it will, then heat until it becomes liquid.

Add to the liquid 1 part by weight of New Orleans molasses and mix well. This will give a very flexible mould.

MOULDS FOR PLASTER-CASTS.—Take the very best glue you can get, place it in cold water at night, the next morning take it out; you will find it swollen: the water it has absorbed during the night is sufficient to melt it by heat; mix then as much thick glycerine with it as you had glue, and keep the vessel containing them in a steam- or water-bath till all the water is about evaporated and there is left as much in weight as the weight of the dry glue and glycerine taken together amounted to. This will make a compound of glue and glycerine which will never dry, and a mould of it can be used over and over again.

A FIRE-PROOF ROOFING.—A fire-proof roofing, and one unaffected by the heat of the sun's rays and that will not melt or run, is made by adding burned lime (ground but not slaked) to coal-tar. Boil together in the proportion of 15 pounds of lime to 100 pounds tar. To avoid the tar boiling over, stir the lime in the boiling tar. The mixture must be put on while hot.

HOW TO MIX PLASTER OF PARIS.—In mixing plaster of Paris do not pour the water on the plaster, but put the water in the bowl and shake or sift in the plaster until the water will take no more. Do not stir it until all the plaster has been put in, and then stir very little. Stirring it only hastens the setting. To retard the setting add a little glue-water.

TINTING OR COLORING OF WALLS.—Plastered walls on which it is not desired to put paper for some time can be tinted or colored by adding a little coloring matter to the skim or finish coat of plaster. The tint or color depending on the amount of coloring matter used.

The following colors can be obtained in various shades by using the material indicated:

For blue, use ultramarine blue.

For black, use lampblack or ivory black.

For green, use a mixture of yellow and blue.

For brown, use brown umber.

For red, use Venetian or Indian red.

For yellow, use chrome yellow.

For orange, use a mixture of red and yellow.

A Cement "Marble."—Under French patents the *Journal of the Society of Chemical Industry* gives the following process of manufacturing artificial marble from cement.

Portland cement is mixed with mineral colors, and moulded into objects with water containing sodium silicate and potassium silicate. After allowing the mass to dry for several days, it is placed in a mixture of 5 litres of "silicious" water and 1 litre of potassium silicate solution, which is then heated and kept boiling for 24 hours. The mass obtained is dried and polished as usual.

How to Prepare Kalosmine.—Soak 1 pound white glue over night, then dissolve it in boiling water, and add 20 pounds of Paris white, diluting with water until the mixture is of the consistency of cream or rich milk. To tint the above add colors as follows:

Lilac.—Add to the kalsomine 2 parts of Prussian blue and 1 of vermilion, stirring thoroughly, and taking care not to give the mixture too bright a color.

Gray.—Add raw umber, with a little lampblack.

Rose.—Three parts of vermilion and 1 of red lead, added in very small quantities until the desired shade is produced.

Lavender.—Mix a light blue and tint it slightly with vermilion.

Straw.—Chrome yellow, with a little Spanish brown.

Buff.—Two parts Indian yellow and 1 part burnt sienna.

To Prevent Dampness in Tool-chests.—Keep several pieces of lime in the chest which will absorb all moisture and prevent tools from rusting. The lime can be kept in an open tin can or box.

Red Stain for Brick or Concrete.—Take 7 pounds new slaked lime, 14 pounds of dry red ochre, 1 pound of alum, and ½ pound of common salt; dissolve in warm water and apply while warm.

Wash to Whiten Dirty Plastered Walls.—Boil 1 part glue in water until dissolved. Then add 5 parts zinc white, mix with hot water until the consistency of cream, and apply with a whitewash brush. This will not rub off and can be painted over at any time as it acts as a size on the plaster.

MENSURATION TABLES, ETC.

LINEAR MEASURE.

1 hair's breadth	=	$\frac{1}{48}$ inch.
3 barleycorns (lengthwise)	=	1 inch.
7.92 inches	=	1 link.
12 inches	=	1 foot = 0.3048 metre.
3 feet	=	1 yard = 0.91438 metre.
$5\frac{1}{2}$ yards	=	1 rod, perch, or pole.
4 poles or 100 links	=	1 chain.
10 chains	=	1 furlong.
8 furlongs	=	1 mile = 1.6093 kilometres = 5280 ft.
3 miles (nautical)	=	1 league.
1 line	=	$\frac{1}{12}$ inch.
1 nail (cloth measure)	=	$2\frac{1}{4}$ inches.
1 palm	=	3 inches.
1 hand (used for height of horses)	=	4 inches.
1 span	=	9 inches.
1 cubit	=	18 inches.
1 pace (military)	=	$2\frac{1}{2}$ feet.
1 pace (common)	=	3 feet.
1 Scotch ell	=	37.06 inches.
1 vara (Spanish)	=	33.3 inches.
1 English ell	=	45 inches.
1 fathom	=	6 feet.
1 cable's length	=	120 fathoms.
1 "knot"	=	6082.66 feet.
1 degree of equator	=	69.1613 statute miles.
1 degree of meridian	=	69.046 statute miles
1 degree of equator	=	60 geographical miles.
1 degree of meridian	=	59.899 geographical miles.
1.1527 statute miles	=	1 geographical mile.
6086.07 feet	=	1 minute of longitude = 1 nautical mile.

SQUARE OR SURFACE MEASURE.

144 square inches	=	1 square foot.
9 square feet	=	1 square yard = 1296 square inches.
100 square feet	=	1square (builders' measure).

LAND MEASURE.

$30\frac{1}{4}$ square yards........	=1 square rod.
40 square rods..........	=1 square rood=1210 square yards.
4 square roods.........	=1 acre=4840 square yards.
640 acres................	=1 square mile.
208.71 feet square.......	=1 acre.
1 square mile..........	=1 section of land.
160 acres................	$=\frac{1}{4}$ section of land.

CUBIC MEASURE.

1728 cubic inches...........	=1 cubic foot.
27 cubic feet..............	=1 cubic yard.
128 cubic feet..............	=1 cord.
40 cubic feet..............	=1 American shipping ton.
42 cubic feet..............	=1 British shipping ton.
108 cubic feet..............	=1 stack of wood.
24.75 cubic feet of stone......	=1 perch.

Note.—In Oklahoma, North Dakota, South Dakota, and Ohio a perch is fixed at 25 cu. ft. of stone. In Delaware it is $24\frac{3}{4}$ cu. ft. in walls, 27 cu. ft. when piled on the ground, 30 cu. ft. when in a boat, and $30\frac{1}{2}$ cu. ft. in cars. In Colorado a perch of stone in mason work is $16\frac{1}{2}$ cu. ft., and for brickwork measure laid in a wall, 22 bricks per cubic foot for a foot wall and 15 bricks for what is known as an 8-inch wall. In Philadelphia 22 cu. ft. is considered a perch.

AVOIRDUPOIS WEIGHT (ORDINARY COMMERCIAL WEIGHT).

16 drams........... =	1 ounce, oz.
16 ounces........... =	1 pound, lb.
28 lbs. (old)......... =	1 quarter, qr.
4 quarters (old), 100 lbs., pounds .. =	1 hundredweight.
20 hundredweight... =	1 ton.
100 pounds.......... =	1 cental.
175 troy pounds...... =	144 avoirdupois.
1 troy pound....... =	5760 grains.
1 avoirdupois pound =	7000 grains.

Avoirdupois weight is used to weigh all coarse articles, as hay, meat, fish, potash, groceries, flax, butter, cheese, etc., and metals, except precious metals. Formerly the usual custom was to allow 112 pounds for a hundredweight and 28 pounds for a

quarter, but this practice has very nearly passed away. The custom-house still adheres to the old usage.

APOTHECARIES' MEASURE—LIQUID.

60 minims or drops, m.,	=1 fluid drachm.
8 fluid drachms......	=1 fluid ounce.
16 fluid ounces.........	=1 pint (octarius).
8 pints...............	=1 gallon (congius).

These apothecarie ' weights and measures are used by apothecaries and physicians in compounding medicines, but drugs and medicines are bought and sold by avoirdupois weight.

The standard avoirdupois pound is the weight of 27.7015 cubic inches of distilled water weighed in air at 39.1°, the barometer at 30 inches.

APOTHECARIES' WEIGHT—DRY.

20 grains..	=1 scruple.
3 scruples	=1 dram.
8 drams..	=1 ounce.
12 ounces	=1 pound.

LIQUID OR WINE MEASURE.

4	gills...................	=1 pint, pt.
2	pints...................	=1 quart, qt.
4	quarts................	=1 gallon, gal.
42	gallons................	=1 tierce.
1½	tierces or 63 gallons....	=1 hogshead, hhd.
84	gallons................	=1 puncheon.
1½	puncheons or 126 gallons	=1 pipe.
2	pipes..................	=1 tun.
231	cubic inches............	=1 gallon.
10	gallons................	=1 anker.
18	"	=1 runlet.
31½	"	=1 barrel.

This measure is used to measure water, wine, spirits, cider, oil, honey, etc. In London the gill is usually called a quartern.

ALE OR BEER MEASURE.

2	pints.....	=1 quart.
4	quarts....	=1 gallon.
9	gallons....	=1 firkin.
2	firkins....	=1 kilderkin.
2	kilderkins	=1 barrel.
$1\frac{1}{2}$	barrels....	=1 hogshead.
$1\frac{1}{3}$	hogsheads	=1 puncheon.
$1\frac{1}{2}$	puncheons	=1 butt.

Used to measure beer, ales, porter, etc. An ale gallon measures 282 cubic inches.

ENGLISH WINE MEASURE.

18	U. S. gallons....	=1 runlet.
25	English gallons	=1 tierce.
42	U. S. gallons	
$7\frac{1}{2}$	English gallons..	=1 firkin of beer.
4	firkins..........	=1 barrel.
$52\frac{1}{4}$	English gallons	=1 hogshead.
63	U. S. gallons	

DRY MEASURE.

2 pints...	=1 quart ..	= 67.2	cubic inches.
4 quarts.	=1 gallon ..	= 288.8	" "
2 gallons.	=1 peck....	= 537.6	" "
4 pecks..	=1 bushel..	=2150.42	" "
36 bushels	=1 chaldron	= 57.244	" feet.
4 bushels (in England)	=1 coon.		
2 coons " "	=1 quarter.		
5 quarters " "	=1 wey.		
2 weys " "	=1 last.		

A gallon, dry measure, measures $268\frac{4}{5}$ cubic inches.

SURVEYORS' SQUARE MEASURE.

625 square links	=1 square rod, sq. rd.	
16 " rods	=1 " chain, sq. ch.	
10 " chains	=1 acre, A.	
640 acres	=1 square mile, sq. mi.	

36 square miles or 6 miles square = 1 township, tp.

SURVEYORS' LONG MEASURE.

7.92 inches . . = 1 link.
25 links. . . . = 1 pole.
100 links. . . . = 1 chain.
10 chains. . = 1 furlong.
8 furlongs = 1 mile.

Used by surveyors, civil engineers, etc., in measuring distances.

MEASURE OF TIME.

60 seconds, sec. . . . . . = 1 minute, min.
60 minutes. . . . . = 1 hour, hr.
24 hours. . . . . = 1 day, dy
7 days. . . . . = 1 week, wk.
2 weeks. . . . . = 1 fortnight.
4 weeks. . . . . = 1 month, mo.
13 months 1 day 6 hrs. = 1 Julian year.
365 days 6 hours. . . . . . = 1 Julian year.
366 days. . . . . = 1 leap year.
12 calendar months . . = 1 year.

Used for computing time.

CIRCULAR MEASURE.

60 seconds, ″. . = 1 minute, ′.
60 minutes. . . . = 1 degree, °.
30 degrees. . . . = 1 sign, s.
90 degrees. . . . = 1 quadrant.
12 signs . . . . . . = a circle.
4 quadrants, 360 degrees . . } = a circumference of a circle.

Used in measuring latitude, longitude, etc.

TROY WEIGHT.

Used in Weighing Gold or Silver.

24 grains. . . . . . . = 1 pennyweight.
20 pennyweights = 1 ounce.
12 ounces. . . . . . = 1 pound.

A carat of the jewellers, for precious stones, is, in the United States, 3.2 grains; in London, 3.17 grains; in Paris 3.18 grains are divided into 4 jewellers' grains. In troy, apothecaries', and avoirdupois weights the grain is the same.

MEASURES OF VALUE.

U. S. Standard.

10 mills. . = 1 cent.
10 cents. . = 1 dime.
10 dimes = 1 dollar.
10 dollars = 1 eagle.

The standard of gold and silver is 900 parts of pure metal and 100 parts of alloy to 1000 parts of coin.

WEIGHT OF COIN.

Double eagle.......	= 516 troy grains.
Eagle..............	= 258 troy grains.
Dollar (gold).......	= 25.8 troy grains.
Dollar (silver)......	= 412.5 troy grains.
Half dollar.........	= 192 troy grains.
5-cent piece (nickel)	= 77.16 troy grains.
3-cent piece (nickel)	= 30 troy grains.
Cent (copper)......	= 48 troy grains.

NUMBER OF ENGLISH OR UNITED STATES YARDS IN MILES OF DIFFERENT NATIONS.

Name.	Yards.	Name.	Yards.
Arabian...............	2,148	Luthenian.............	9,784
Bohemian.............	10,187	Oldenburg............	10,820
Brebant...............	6,082	Persian (paisang)......	6,082
Burgundy.............	6,183	Polish (long)...........	8,101
Chinese (Hls)..........	682	Polish (short)..........	6,095
Dutch (Ure)...........	6,395	Portuguese (leguos)....	6,760
Danish...............	8,244	Prussian..............	8,498
English (U. S.).........	1,760	Roman (modern)......	2,035
English (geographical)..	2,025	Roman (ancient).......	1,613
Flemish...............	6,869	Russian (verst)........	1,167
German (geographical) .	8,100	Saxon.................	9.905
Hamburg..............	8,244	Scotch................	1,984
Hanover..............	11,559	Silesian...............	7,083
Hesse................	10,547	Spanish (leguas).......	4,630
Hungarian............	9,113	Spanish (com.)........	7,416
French (art leagues) ...	4,860	Swiss.................	9,166
French (marine).......	6,075	Swedish..............	11,704
Legal Le'g'e (2000 toises)	4,263	Turkey................	1,821
Irish.................	3,338	Tuscan................	1,808
Italian................	2,025	Vienna (post mile).....	8,296

TABLE OF MISCELLANEOUS WEIGHTS.

14 pounds.	=1 stone (horseman's weight).
56 pounds.	=1 firkin of butter.
64 pounds.	=1 firkin of soft soap.
112 pounds.	=1 barrel of raisins.
256 pounds.	=1 pack of soft soap.
196 pounds.	=1 barrel of flour.
200 pounds.	=1 barrel of beef, pork, or fish.
280 pounds.	=1 barrel of salt, New York.
22 stones (301 lbs.).	=1 sack of wool.
17 stones 2 lbs. (240 lbs.)	=1 pack of wool.
60 pounds.	=1 truss of hay (new).
50 pounds.	=1 truss of hay (old).
40 pounds.	=1 truss of straw.
400 pounds.	=1 bale of cotton.
100 pounds.	=1 quintal of fish.

COMMON WEIGHTS AND MEASURES AND THEIR METRIC EQUIVALENTS.

An inch = 2.54 centimetres.
A foot = .3048 metre.
A yard = .9144 metre.
A rod = 5.029 metres.
A mile = 1.6093 kilometres.
A square inch = 6.452 square centimetres.
A square foot = .0929 sq. m.
A square yard = .8361 sq. m.
An acre = .4047 hectare.
A square mile = 259 hectares.
A cubic foot = .02832 cu. m.
A cubic yard = .7646 cu. m.
A cord = 3.624 steres,
A liquid quart = .9465 litre.
A gallon = 3.786 litres.
A dry quart = 1.101 litres
A peck = 8.811 litres.
A bushel = 35.24 litres.
An ounce avoirdupois = 28.35 grams.
A pound avoirdupois = .4336 kilogram.
A ton = .9072 tonneau.
A grain troy = .0648 gram.
An ounce troy = 31.104 grms.
A pound troy = .3732 kgrm.

U. S. Land Measure.

A range is a line of townships running north and south, and is known by its number east or west of the principal meridian.

A township is divided into 36 equal squares, called sections each 1 mile square, and containing 640 acres.

A section is variously divided for purposes of sale. The U. S. Land Office recognizes the following divisions:

Half-section...............	$=1\times\frac{1}{2}$ mile	$=\frac{1}{2}$ sq. mile	$=320$ acres
Quarter-section............	$=\frac{1}{2}\times\frac{1}{2}$ mile	$=\frac{1}{4}$ sq. mile	$=160$ acres
Half-quarter-section	$=\frac{1}{2}\times\frac{1}{4}$ mile	$=\frac{1}{8}$ sq. mile	$=80$ acres
Quarter-quarter-section....	$=\frac{1}{4}\times\frac{1}{4}$ mile	$=\frac{1}{16}$ sq. mile	$=40$ acres

Old French Linear and Land Measure.

12 lines.............	=1 inch	6 feet...........	=1 toise
12 inches...........	=1 foot	32 toises.........	=1 arpent

1024 sq. toises...... =1 sq. arpent

The French foot equals 12.79 English inches.

The arpent is the old French name for acre, and contains nearly $\frac{5}{6}$ of an English acre.

SPANISH LAND MEASURE.

Sometimes used in Texas, Mexico New Mexico, Arizona, and California.

26,000,000	sq. varas (sq. of 5099	varas) = { 1 league 1 labor	=4605.5	acres.
1,000,000	sq. varas (sq. of 1000	varas) = 1 labor	= 177.136	acres.
25,000,000	sq. varas (sq. of 5000	varas) = 1 league	=4428.4	acres.
12,500,000	sq. varas (sq. of 3535.5	varas) = $\frac{1}{2}$ league	=2214.2	acres.
8,333,333	sq. varas (sq. of 2886.7	varas) = $\frac{1}{3}$ league	=1476.13	acres.
6,250,000	sq. varas (sq. of 2500	varas) = $\frac{1}{4}$ league	=1107.1	acres.
7,225,600	sq. varas (sq. of 2688	varas)	=1280	acres.
3,612,800	sq. varas (sq. of 1900.8	varas) = 1 section	= 640	acres.
1,806,400	sq. varas (sq. of 1344	varas) = $\frac{1}{2}$ section	= 320	acres.
903,200	sq. varas (sq. of 950.44	varas) = $\frac{1}{4}$ section	= 160	acres.
451,600	sq. varas (sq. of 672	varas) = $\frac{1}{8}$ section	= 80	acres.
225,800	sq. varas (sq. of 475	varas) = $\frac{1}{16}$ section	= 40	acres.
5,645.376	sq. varas (sq. of 75 137	varas) = 4840 sq. yd.	= 1	acre.

To find the number of acres in any number of square varas multiply the latter by 177 (or to be more exact, by $177\frac{1}{8}$), and cut off six decimals.

1 vara = $33\frac{1}{3}$ inches. 1900.8 varas = 1 mile.

WEIGHTS AND MEASURES OF THE PHILIPPINES.

1 polgrada (12 linea)	=	.927	inch
1 pie	=	11.125	inches
1 vara	=	33.375	inches
1 gantah	=	.8796	gallon
1 caban	=	21.991	gallons
1 libra (16 onzo)	=	1.0144	lb. av.
1 arroba	=	25.360	lb. av.
1 catty (16 tael)	=	1.94	lb. av.
1 pecul (100 catty)	=	139.482	lb. av.

Legal Weights (in Pounds) per Bushel of Various Commodities Prepared by Department of Commerce and Labor, Bureau of Standards, Washington.

The list below includes products for which legal weights have been fixed in but one or two States.

Apple seeds, 40 pounds (Rhode Island and Tennessee).
Beggarweed seed, 62 pounds (Florida).
Blackberries, 32 pounds (Iowa); 48 pounds (Tennessee); dried, 28 pounds (Tennessee).
Blueberries, 42 pounds (Minnesota).
Bromus inermus, 14 pounds (North Dakota).
Cabbage, 50 pounds (Tennessee).
Canary seed, 60 pounds (Tennessee).
Cantaloupe melon, 50 pounds (Tennessee).
Cement, 80 pounds (Tennessee).
Cherries, 40 pounds (Iowa); with stems, 56 pounds (Tennessee); without stems, 64 pounds (Tennessee).
Chestnuts, 50 pounds (Tennessee); 57 pounds (Virginia).
Chufa, 54 pounds (Florida).
Cottonseed, staple, 42 pounds (South Carolina).
Cucumbers, 48 pounds (Missouri and Tennessee); 50 pounds (Wisconsin).
Currants, 40 pounds (Iowa and Minnesota).
Feed, 50 pounds (Massachusetts).
Grapes, 40 pounds (Iowa); with stems, 48 pounds (Tennessee); without stems, 60 pounds (Tennessee).
Guavas, 54 pounds (Florida).
Hickory nuts, 50 pounds (Tennessee).

Hominy, 60 pounds (Ohio); 62 pounds (Tennessee).
Horseradish, 50 pounds (Tennessee).
Italian rye-grass seed, 20 pounds (Tennessee).
Johnson grass, 28 pounds (Arkansas).
Kaffir corn, 56 pounds (Kansas).
Kale, 30 pounds (Tennessee).
Land plaster, 100 pounds (Tennessee).
Meal, 46 pounds (Alabama); unbolted, 48 pounds (Alabama).
Middlings, fine, 40 pounds (Indiana); coarse middlings, 30 pounds (Indiana).
Millet, Japanese barnyard, 35 pounds (Massachusetts).
Mustard, 30 pounds (Tennessee).
Plums, 40 pounds (Florida); 64 pounds (Tennessee).
Plums, dried, 28 pounds (Michigan).
Popcorn, 70 pounds (Indiana and Tennessee); in the ear, 42 pounds (Ohio).
Prunes, dried, 28 pounds (Idaho); green, 45 pounds (Idaho).
Quinces, 48 pounds (Florida, Iowa, and Tennessee).
Rape-seed, 50 pounds (Wisconsin).
Raspberries, 32 pounds (Kansas); 48 pounds (Tennessee).
Rhubarb, 50 pounds (Tennessee).
Sage, 4 pounds (Tennessee).
Salads, 30 pounds (Tennessee).
Sand, 130 pounds (Iowa).
Spelt or spiltz, 40 pounds (North Dakota); 45 pounds (South Dakota).
Spinach, 30 pounds (Tennessee).
Strawberries, 32 pounds (Iowa); 48 pounds (Tennessee).
Sugar-cane seed, 57 pounds (New Jersey.)
Velvet-grass seed, 7 pounds (Tennessee).
Walnuts, 50 pounds (Tennessee).

On the pages following are tabulated the products for which legal weights have been more widely established.

LEGAL WEIGHTS (IN POUNDS) PER BUSHEL.

	Apples.			Beans.								
	Apples.*	Dried Apples.	Barley.	Beans.*	Castor Beans (shelled).	Beets.	Blue-grass Seed.	Bran.*	Broom-corn Seed.	Buckwheat.	Carrots.	Charcoal.
U. S.	....	....	48	....	50	....	....	....	....	42	....	....
Alabama.	....	21	47	60	....	....	....	....	....	....	....	....
Arizona.	....	....	45	*a*55	....	....	....	....	....	....	....	....
Arkansas.	*b* 50	24	48	*a*60	....	....	14	20	48	52	....	....
California.	....	....	50	....	....	....	....	....	....	40	....	....
Colorado.	....	....	48	60	....	....	14	....	....	52	....	....
Conn.	48	25	48	60	....	*c* 60	....	20	....	48	50	20
Delaware.	....	....	....	....	....	....	....	....	....	....	....	20
Florida.	*b* 48	24	48	*d*60	48	....	....	20	....	....	....	....
Georgia.	....	24	47	*e* 60	....	....	14	*f* 20	....	52	....	....
Hawaii.	....	....	48	....	....	....	....	....	....	....	....	....
Idaho.	*b* 45	28	48	....	....	....	....	....	....	42	....	....
Illinois.	....	24	48	*c* 60	46	....	14	20	....	52	....	....
Indiana.	....	25	48	60	46	....	14	....	....	50	....	....
Iowa.	48	24	48	60	46	....	14	20	30	52	....	20
Kansas.	*b* 48	24	48	60	46	....	*g*14	20	....	50	....	....
Kentucky	....	24	47	*c* 60	*45	....	14	20	....	56	....	....
Louisiana.	....	....	48	....	....	....	....	....	....	....	....	....
Maine.	44	....	48	60	....	60	....	....	....	48	50	....
Maryland	....	....	....	....	....	....	....	....	....	....	....	20
Mass.	48	25	48	*h* 60	....	....	....	20	....	48	50	....
Michigan.	48	22	48	60	46	....	14	....	....	48	....	....
Minnesota	*b*50	28	48	60	....	50	14	....	57	50	45	20
Mississippi	....	26	48	*e* 60	46	....	14	20	....	48	....	....
Missouri.	48	24	48	*i* 60	46	....	14	20	....	52	50	....
Montana.	45	....	48	60	....	50	14	20	....	52	50	....
Nebraska	....	24	48	*e* 60	46	....	14	20	....	52	....	....
New Ham.	....	....	....	62	....	....	....	....	....	....	....	....
N. Jersey.	50	25	48	60	....	....	....	....	....	50	....	....
New York	48	25	48	60	....	....	....	20	....	48	50	....
N. Car.	....	....	48	....	....	....	....	....	....	50	....	....
N. Dakota	50	....	48	60	....	60	....	20	30	42	....	....
Ohio.	50	24	48	60	....	56	....	....	....	50	50	....
Oklahoma	....	....	48	60	....	60	....	20	30	42	....	....
Oregon.	45	28	46	....	....	....	....	....	....	42	....	....
Penn.	....	....	47	....	....	....	....	....	....	48	....	*jk*18
R. Island.	48	25	48	60	46	50	....	20	....	48	50	20
S. Dakota	....	....	48	60	....	60	....	20	30	42	....	....
Tennessee	*b*50	24	48	*il* 60	46	50	14	20	42	50	50	22
Texas.	45	28	48	*c* 60	....	....	....	20	....	42	....	22
Vermont.	46	....	48	62	....	60	....	....	....	48	50	....
Virginia.	....	28	48	*c* 60	....	....	14	....	....	52	....	....
Wash.	*b*45	28	48	....	....	....	....	....	....	42	....	....
W. Va.	....	25	48	60	....	....	....	....	....	52	....	....
Wisconsin	50	25	48	60	....	50	....	20	....	50	50	....

* Not defined.

a Small white beans, 60 pounds.
b Green apples.
c Sugar beets and mangel wurzel.
d Shelled beans, 60 pounds; velvet beans, 78 pounds.
e White beans.
f Wheat bran.
g English blue-grass seed, 22 pounds; native blue-grass seed, 14 pounds.
h Soy beans, 58 pounds.
i Green unshelled beans, 30 pounds.
j Commercially dry, for all hard woods.
k Fifteen pounds, commercially dry, for all soft woods.
l Dried beans.

LEGAL WEIGHTS (IN POUNDS) PER BUSHEL—(*Continued*).

	Clover Seed.	Coal.						Coke.	Corn.				Corn Meal.*
		Coal.*	Anthracite Coal.	Bituminous Coal.	Cannel Coal.	Mineral Coal.	Stone Coal.		Corn.*	Corn in Ear, Husked.	Corn in Ear, Unhusked.	Shelled Corn.	
U. S.				80					56				48
Alabama.										70	75	56	
Arizona.									54				
Arkansas.	60									70	74	56	48
Colorado.	60	80				80				70			50
Conn.	60		80										
Florida.											70	56	48
Georgia.	60						80			70		56	48
Idaho.	60												
Illinois.	60						80			70		56	48
Indiana.	60					80				(*a*)		56	50
Iowa.	60						80	38		*b* 70		56	
Kansas.	60						80			*c* 70			50
Kentucky	60	76	76	76	76	76	76		*d* 70			56	50
Louisiana.									56				
Maine.									56				*e* 50
Mass.	60											*f* 50	50
Michigan.	60					80				*b* 70		56	50
Minnesota	60	80								70		56	
Mississippi	60						80			72		56	48
Missouri.	60					80					70	56	50
Montana.	60					76				70		56	50
Nebraska	60						80			70		56	50
N. Hamp.									56				50
N. Jersey.	64												
New York	60												50
N. Car.	60												
N. Dakota	60						80			70		56	
Ohio.	60			80	70			40		68		56	
Oklahoma	60						80			70		56	
Oregon.	60												
Penn.	60	*g* 75		76				40	58				
R. Island.	60	80						40		70		56	50
S. Car													*h* 48
S. Dakota	60						80			70		56	
Tennessee	*i* 60						80	40		70	*j* 74	56	
Texas.	60						80			70	72	56	
Vermont.	60												
Virginia.	60						80			70		56	50
Wash.	60												
W. Va.	60				80				56				
Wisconsin	60												50

* Not defined.

a Corn in ear, 70 pounds until Dec. 1 next after grown; 68 pounds thereafter.
b In the cob.
c Indian corn in ear.
d Corn in ear, from Nov. 1 to May 1, following, 70 pounds; 68 pounds from May 1 to Nov. 1.
e Indian-corn meal.
f Cracked corn.
g Standard weight in borough of Greensburg.
h Standard weight bushel corn meal, bolted or unbolted, 48 pounds.
i Red and white.
j Green unshelled corn, 100 pounds.

LEGAL WEIGHTS (IN POUNDS) PER BUSHEL—(*Continued*).

	Corn Meal, Bolted.	Corn Meal, Unbolted.	Cottonseed.			Cranberries.	Flaxseed (Linseed).	Gooseberries.	(Plastering) Hair.	Hemp Seed.	Herds Grass.	Hungarian Grass Seed.	Indian Corn or Maize.
			Cottonseed.*	Sea Island Cottonseed.	Upland Cottonseed.								
U. S.	....	....	....	....	....	....	56	....	....	....	....	....	....
Alabama.	....	....	32	....	....	....	....	....	....	....	....	....	....
Arkansas.	....	....	33⅓	....	....	....	56	....	....	....	....	....	....
California.	....	....	....	....	....	....	....	....	....	....	....	....	52
Colorado.	....	....	....	....	....	....	....	....	....	44	....	....	56
Conn.	....	....	....	44	30	....	55	....	....	....	45	....	56
Delaware	44	48	....	....	....	....	....	....	....	....	....	....	56
Florida.	....	....	32	46	....	....	....	....	....	....	....	....	....
Georgia.	....	....	30	....	....	....	56	....	8	44	....	....	....
Hawaii.	....	....	....	....	....	....	....	....	....	....	....	....	56
Idaho.	....	....	....	....	....	....	56	....	....	....	....	....	56
Illinois.	....	....	....	....	....	....	56	....	8	44	....	....	....
Indiana.	....	....	....	....	....	33	....	....	....	44	....	....	....
Iowa.	....	....	....	....	....	....	56	40	....	44	....	50	....
Kansas.	....	....	....	....	....	....	56	....	*a*8	44	....	50	*b*56
Kentucky	....	....	....	....	....	....	56	....	8	44	....	50	....
Maine.	....	....	....	....	....	....	....	....	11	....	45	....	....
Mass.	....	....	....	44	30	....	55	....	....	....	45	....	*b*56
Michigan.	....	....	....	....	....	40	56	....	....	44	....	50	....
Minnesota	....	....	....	....	....	36	....	40	*a*8	50	....	48	....
Mississippi	44	48	32	....	....	....	56	....	....	44	....	50	....
Missouri.	....	....	33	....	....	....	56	....	....	44	....	48	....
Montana.	....	....	....	....	....	....	56	....	....	44	....	50	....
Nebraska	....	....	....	....	....	....	56	....	8	44	....	50	....
N. Jersey.	....	....	....	....	....	....	55	....	....	....	....	....	56
New York	....	....	....	44	30	....	55	....	....	....	45	....	56
N. Car.	46	48	30	....	....	....	55	....	....	....	....	....	56
N. Dakota	....	....	....	....	....	....	56	....	....	....	....	....	....
Ohio.	....	....	....	....	....	....	56	....	....	44	....	50	....
Oklahoma	....	....	....	....	....	....	56	....	....	....	....	....	....
Oregon.	....	....	....	....	....	....	....	....	....	....	....	....	56
Penn.	....	....	....	....	....	....	....	....	....	....	....	....	56
R. Island.	....	....	....	44	30	....	56	....	....	44	....	50	....
S. Car.	46	48	30	(*c*)	....	....	....	....	....	....	....	....	....
S. Dakota	....	....	....	....	....	....	56	....	....	....	....	....	....
Tennessee	50	48	28	....	....	....	56	48	8	44	....	48	....
Texas.	....	....	32	....	....	....	56	....	....	44	....	48	....
Vermont.	....	....	....	....	....	....	....	....	....	....	45	....	56
Virginia.	....	....	32	....	....	....	56	....	8	44	12	48	....
Wash.	....	....	....	....	....	....	56	....	....	....	....	....	56
W. Va.	....	....	....	....	....	....	56	....	....	....	....	....	....
Wisconsin	....	....	....	44	30	....	56	....	8	44	....	48	56

* Not defined.

a Unwashed plastering hair, 8 pounds; washed plastering hair, 4 pounds.

b Shelled.

c Matured.

LEGAL WEIGHTS (IN POUNDS) PER BUSHEL—(*Continued*).

	Lime.					Onions.					Peaches.	
	Lime.*	Unslaked Lime.	Malt.	Millet.	Oats.	Onions.*	Onion Sets.	Orchard Grass Seed.	Osage Orange Seed.	Parsnips.	Peaches.*	Dried Peaches, Peeled.
U. S			34		32							
Alabama					32							38
Arizona					32							
Arkansas				50	32	57						33
California					32							
Colorado	80				32	57						
Conn.	70				32	52				45		33
Florida				50	32	56					*a*54	33
Georgia		80			32	57						38
Hawaii					32							
Idaho					36							
Illinois		80	38		32	57						
Indiana			*b*35	50	32	48		14	33	55		
Iowa	80			50	32	57			32		48	
Kansas		80	32	50	32	57						
Kentucky		35		50	*c*32	57	*d*36	14				39
Maine					*e*32	52				45		
Maryland					26							
Mass.	70				32	52						33
Michigan	70			50	32	54		14	33			28
Minnesota	80			48	32	52		14		42		28
Mississippi		80	38	50	32	57						33
Missouri			38	50	32	57	*f*28	14	36	44	48	33
Montana		80	30		32	57				50		
Nebraska		80	30	50	32	57	25		32			33
N. Hamp					32							
N. Jersey					30	57						33
New York	70				32	57						33
N. Car.					32							
N. Dakota	80			50	32	52						
Ohio	70		34	50	32	55					48	33
Oklahoma	80				32	52						
Oregon					32							28
Penn.					32	50						
R. Island	70		38	50	32	50				50	48	33
S. Dakota	80				32	52						
Tennessee	(*g*)	80		*h*50	32	*i*56	*j*28	14	33	50	*l*50	26
Texas				50	32	57					50	28
Vermont					32	52						
Virginia		80	33	50	30	57	23	14	34			40
Washington					32							28
W. Virginia					32							33
Wisconsin	70	80	34	50	32	57				44		33

* Not defined.

a Green peaches.
b Malt rye.
c Shelled.
d Bottom onion sets.
e Strike measure.
f Top onion sets.
g Slaked lime, 40 pounds.
h German Missouri and Tennessee millet seed.
i Matured onions.
j Button onion sets, 32 pounds.
l Matured.

LEGAL WEIGHTS (IN POUNDS) PER BUSHEL—(*Continued*).

	Dried Peaches, Unpeeled.	Peanuts.	Pears.*	Pease.			Potatoes.			Red Top.	Rough Rice.	Rice Corn.	Rutabagas.
				Ground Pease.	Green Pease, Unshelled.	Pease.*	Potatoes.*	Sweet Potatoes.	White Potatoes.				
U. S.	....	....	....	....	....	60	60	....	....	....	....	....	....
Alabama.	33	....	....	....	....	60	....	55	60	....	....	....	....
Arkansas.	33	....	....	....	....	60	60	50	....	14	....	....	....
Colorado.	....	....	....	....	....	....	60	....	....	....	....	....	....
Conn.	33	....	....	....	....	60	60	54	60	....	45	....	60
D. C.	....	....	....	....	....	....	60	....	....	....	....	....	....
Florida.	....	22	60	....	....	....	....	60	60	....	....	....	....
Georgia.	33	....	....	25	....	60	....	55	60	....	43	....	....
Idaho.	28	....	*a* 45	....	....	....	60	....	....	....	....	....	....
Illinois.	33	....	....	....	....	....	....	50	60	....	....	....	....
Indiana.	33	....	....	....	....	....	60	55	....	....	....	....	....
Iowa.	33	....	....	....	....	....	60	46	....	....	....	....	....
Kansas.	33	....	....	....	....	....	60	50	....	....	....	56	....
Kentucky	....	....	....	24	....	60	60	55	60	....	....	....	....
Maine.	....	....	....	....	....	60	60	....	....	....	....	....	60
Maryland.	....	....	....	....	....	....	56	....	....	....	....	....	....
Mass	....	....	....	....	....	60	60	54	....	....	45	....	....
Michigan	....	....	....	....	....	60	....	56	60	*b* 14	....	....	....
Minnesota	....	....	....	....	....	60	....	55	60	*b* 14	....	....	52
Mississippi	....	....	....	24	....	60	....	60	60	....	....	....	....
Missouri.	....	....	48	....	56	*c* 60	....	56	60	*b* 14	....	....	50
Montana.	....	....	45	....	....	60	60	....	....	....	....	....	....
Nebraska	....	....	....	....	....	60	....	50	60	....	....	....	....
N. Hamp	....	....	....	....	....	60	60	....	....	....	....	....	....
N. Jersey.	....	....	....	....	....	60	....	54	60	....	....	....	....
New York	....	....	....	....	....	60	....	54	60	....	45	....	....
N Car	....	22	....	....	....	60	....	....	....	....	44	....	....
N. Dakota	....	....	....	....	....	60	....	46	60	....	....	....	....
Ohio	....	....	....	....	....	60	....	50	60	....	....	....	....
Oklahoma	....	....	....	....	....	60	....	46	60	....	....	....	....
Oregon.	....	....	45	....	....	....	60	....	....	....	....	....	....
Penn.	....	....	....	....	....	....	56	....	....	....	....	....	....
R. Island.	....	....	....	....	....	*c* 60	....	54	60	....	....	....	....
S Dakota	....	....	....	....	....	60	....	46	60	....	....	....	....
Tennessee	....	23	*d* 56	....	30	60	....	50	60	*b* 14	....	....	....
Texas	....	....	....	....	....	....	....	55	60	....	....	....	....
Vermont.	....	....	....	....	....	60	60	....	....	....	....	....	....
Virginia.	32	22	....	....	....	*e* 60	....	56	56	12	....	....	....
Wash.	....	....	*a* 45	....	....	....	60	....	....	....	....	....	....
W Va.	....	....	....	....	....	....	60	....	....	....	....	....	....
Wisconsin	....	....	....	....	....	60	....	54	60	....	45	....	56

* Not defined.

a Green.
b Seed
c Including split pease.
d Matured pears, 56 pounds; dried pears, 26 pounds.
e Black-eyed pease.

LEGAL WEIGHTS (IN POUNDS) PER BUSHEL—(*Continued*)

	Rye Meal.	Rye.	Salt.			Shorts.*	Sorghum Seed.	Tomatoes.	Timothy Seed.	Turnips.		Wheat.
			Salt.*	Fine Salt.	Coarse Salt.					Turnips.*	Common English Turnips.	
U. S.	....	56	....	....	....	....	....	....	....	....	....	60
Alabama	....	56	....	....	....	....	....	....	....	55	....	60
Arizona	....	56	....	....	....	....	....	....	....	....	....	60
Arkansas	....	56	50	....	....	....	50	....	60	57	....	60
California	....	54	....	....	....	....	....	....	....	....	....	60
Colorado	....	56	80	....	....	....	....	....	45	....	....	60
Conn.	50	56	....	50	70	20	....	....	....	....	50	60
Delaware	....	....	....	....	....	....	....	....	....	....	....	60
Florida	....	56	60	....	....	....	56	....	....	54	....	60
Georgia	....	56	....	....	....	....	....	....	45	55	....	60
Hawaii	....	56	....	....	....	....	....	....	....	....	....	60
Idaho	....	56	....	....	....	....	....	....	....	....	....	60
Illinois	....	56	....	55	50	....	....	....	45	55	....	60
Indiana	....	56	50	....	....	....	....	....	45	55	....	60
Iowa	....	56	50	....	....	....	a30	....	45	....	....	60
Kansas	....	56	50	....	....	....	56	....	45	55	....	60
Kentucky	....	56	50	55	....	....	....	....	45	60	....	60
Louisiana	....	56	....	....	....	....	....	....	....	....	....	60
Maine	50	50	....	60	70	....	....	....	....	....	50	60
Maryland	....	....	....	....	....	....	....	60	....	....	....	....
Mass.	50	56	....	50	70	20	....	....	45	....	....	60
Michigan	....	56	56	....	....	....	....	....	45	58	....	60
Minnesota	....	56	....	....	....	....	57	....	45	....	....	60
Mississippi	....	56	50	....	....	....	42	....	45	55	....	60
Missouri	....	56	50	....	....	....	42	45	45	....	42	60
Montana	....	56	50	....	....	....	....	....	45	50	....	60
Nebraska	....	56	50	....	....	....	30	....	45	55	....	60
N. Hamp.	50	56	....	....	....	....	....	....	....	....	....	60
N. Jersey	....	56	....	....	....	....	....	....	....	....	....	60
New York	50	56	....	56	70	20	....	....	45	....	....	60
N. Carolina	....	56	....	....	....	....	....	....	....	....	....	60
N. Dakota	....	56	80	....	....	....	....	....	45	60	....	60
Ohio	....	56	....	....	....	....	....	56	45	60	....	60
Oklahoma	....	56	80	....	....	....	....	....	42	60	....	60
Oregon	....	56	....	....	....	....	....	....	....	....	....	60
Penn.	....	56	....	c62	85	....	....	....	....	....	....	60
R. Island	50	56	....	50	70	20	....	56	45	50	....	60
S. Dakota	....	56	80	....	....	....	....	....	42	60	....	60
Tennessee	....	56	50	....	....	....	50	56	45	50	....	60
Texas	....	56	50	....	....	....	....	55	45	55	....	60
Vermont	....	56	70	....	....	....	....	....	45	60	....	b60
Virginia	....	56	50	....	....	....	....	....	45	55	....	60
Washington	....	56	....	....	....	....	....	....	....	....	....	60
W. Virginia	....	56	....	....	....	....	....	....	45	....	....	60
Wisconsin	50	56	....	50	70	20	....	....	45	42	....	60

* Not defined.

a Sorghum saccharatum seed.
b India wheat, 46 pounds.
c Ground salt, 70 pounds.

RULES RELATIVE TO THE CIRCLE.

To Find Circumference:

Multiply diameter by 3.1416,
or divide " " 0.3183.

To Find Diameter:

Multiply circumference by 0.3183,
or divide " " 3.1416.

To Find Radius:

Multiply circumference by 0.15915,
or divide " " 6.28318.

To Find Side of an Inscribed Square:

Multiply diameter by 0.7071,
or multiply circumference by 0.2251,
" divide " " 4.4428.

To Find Side of an Equal Square:

Multiply diameter by 0.8862,
or divide " " 1.1284,
" multiply circumference by 0.2821,
" divide " " 3.545.

Square.

A side multiplied by 1.4142 equal diameter of its circumscribing circle.

A side multiplied by 4.443 equal circumference of its circumscribing circle.

A side multiplied by 1.128 equal diameter of an equal circle.

A side multiplied by 3.547 equal circumference of an equal circle.

Square inches multiplied by 1.273 equal circle inches of an equal circle.

To Find the Area of a Circle:

Multiply circumference by one-quarter of the diameter,
or multiply the square of diameter by 0.7854,
" " " " " circumference " 0.07958,
" " " " " ½ diameter " 3.1416.

To Find the Surface of a Sphere or Globe:

Multiply the diameter by the circumference,
or multiply the square of diameter by 3.1416,
" " four times the square of radius by 3.1416.

To Find the Weight of Brass and Copper Sheets, Rods, and Bars:

Ascertain the number of cubic inches in piece and multiply same by weight per cubic inch.

Brass, 0.2972.
Copper, 0.3212.

Or multiply the length by the breadth (in feet) and product by weight in pounds per square foot.

TABLE TO FIND AREAS, ETC., OF POLYGONS.

Name of Polygon.	No. of Sides.	A Area.	B Radius of Circumscribed Circle.	C Length of the Side.	D Radius of Inscribed Circle.	Angle Contained between Two Sides.
Triangle.......	3	0.433013	0.5773	1.732	0 2887	60°
Tetragon......	4	1	0.7071	1.4142	0.5	90°
Pentagon......	5	1.720477	0.8506	1.1756	0.6882	108°
Hexagon......	6	2.598076	1	1	0.866	120°
Heptagon.....	7	3.633912	1.1524	0.8677	1.0383	128.57°
Octagon.......	8	4.828427	1.3066	0.7653	1.2071	135°
Nonagon......	9	6 181824	1.4619	0.684	1.3737	140°
Decagon.......	10	7.694209	1.618	0 618	1 5383	144°
Undecagon....	11	9 36564	1.7747	0 5634	1.7028	147 27°
Dodecagon...	12	11.196152	1.9319	0 5176	1.866	150°

To find the area of a regular polygon when the length of one side is given: Multiply the square of the side by the multiplier opposite to the name of the polygon in column A of the following table.

To compute the radius of a circumscribing circle when the length of one side is given: Multiply the length of a side of the polygon by the number in column B.

To compute the length of a side of a polygon that is contained in a given circle when the radius of the circle is given: Muitiply the radius of the circle by the number opposite the name of the desired polygon in column C.

To compute the radius of a circle that can be inscribed in a given polygon when the length of a side is given: Multiply the length of a side of the polygon by the number opposite the name of the polygon in column D.

MULTIPLIERS FOR FACILITATING CALCULATIONS.

Cubic inches × .4103 = lbs. of lead.
Cubic inches × .3225 = lbs. of copper.
Cubic inches × .328 = lbs. of cast copper.
Cubic inches × .268 = lbs. of tin.
Cubic inches × .304 = lbs. of brass.
Cubic inches × .253 = lbs. of zinc.
Cubic inches × .260 = lbs. of cast iron.
Cubic inches × .282 = lbs. of wrought iron.
Cubic inches × .004329 = U. S. gallons.
Cubic inches × .00058 = cubic feet.
Cubic inches × .000466 = U. S. bushel.
Cubic inches of water × .03617 = lbs. avoir.
One cubic inch of water = .0361 lb.
Cubic feet × .03704 = cubic yards.
Cubic feet × .8036 = U. S. bushel.
Cubic feet × 7.48 = U. S. gallons.
Cubic feet of water × 62.42 = lbs. avoir.
One cubic foot of water = 62.42 lbs. avoir.
1.6 cubic feet of water = 1 cwt. (100).
32.04 cubic feet of water = 1 ton (2000).
1.8 cubic feet of water = 1 cwt. (112).
35.88 cubic feet of water = 1 ton (2240).
Square inches × .007 = square feet.
Square feet × .111 = square yards.
Circular inches × .00546 = square feet.
183.346 circular inches = 1 square foot.
Cylindrical inches × .0004546 = cubic feet.
Cylindrical inches × .0034 = U. S. gallons.
Cylindrical inch s of water × .02842 = lbs. avoir.
Cylindrical feet of water × 49.1 = lbs. avoir.
Cylindrical feet × 5.874 = U. S. gallons.
One cylindrical inch of water = .0284 lb.
One cylindrical foot of water = 49.10 lbs.
2200 cylindrical inches = 1 cubic foot.
U. S. bushel × .0495 = cubic yards.
" " × 1.2446 = " feet.
" " × 2150.42 = " inches.

U. S. gallons × .13367 = cubic feet.

U. S. gallon liquid measure × 231 = cubic inches.

13.44 U. S. gal. of water = 1 cwt. (112).

268.8 " " " " = 1 ton (2240).

12 " " " " = 1 cwt. (100).

240 " " " " = 1 ton (2000).

One gallon of water = 8.34 lbs.

One gallon = .13368056 cubic foot.

Lbs. avoirdupois × .009 = cwt. (112).

" " × .00045 = tons (2240).

One pound of water = 27.7 cubic inches.

One pound of water = .16 cubic foot.

Lineal feet × .00019 = miles.

" yards × .0006 = "

" links × .22 = yards.

" " × .66 = feet.

" feet × 1.5 = links.

Square yards × .0002067 = acres.

Acres × 4840 = square yards.

Width in chains × 8. = acres per mile.

Velocity in feet per second × .68 = miles per hour.

Velocity in feet per second × .60 = feet per minute.

Velocity in feet per second × .20 = yards per minute.

Inches per second × 5 = feet per minute.

Inches per second × 300 = feet per hour.

Head of water in feet = pressure of water in lbs. per square foot × .016.

Head in feet × .434 = lbs. per square inch.

Pounds per square inch × 2.3 = head in feet.

Pressure of water in lbs. per square foot = head in feet × 62.32.

One pound pressure of water = 2.042-inch column of mercury.

Column of water 12 inches high, 1 inch diameter = .341 lb.

One atmosphere = 2116.3 lbs. per square foot.

One atmosphere = 33.947 feet of water at 62 degrees Fahrenheit.

One circular mill is the area of a circle .001 inch in diameter.

1,000,000 circular mills = one circular inch.

AREAS OF CIRCLES AND SIDES OF SQUARES OF SAME AREA.

(Diameter multiplied by .8862 equals sides of an equal square.)

Diameter of Circle in Inches.	Area of Circle in Square Inches.	Sides of Square of Same Area in Square Inches.	Diameter of Circle in Inches.	Area of Circle in Square Inches.	Sides of Square of Same Area in Square Inches.	Diameter of Circle in Inches.	Area of Circle in Square Inches.	Sides of Square of Same Area in Square Inches.
1	.785	.89	21	346.36	18.61	41	1320.26	36.34
1½	1.767	1.33	21½	363.05	19.05	41½	1352.66	36.78
2	3.142	1.77	22	380.13	19.50	42	1385.45	37.22
2½	4.909	2.22	22½	397.61	19.94	42½	1418.63	37.66
3	7.069	2.66	23	415.48	20.38	43	1452.20	38.11
3½	9.621	3.10	23½	433.74	20.83	43½	1486.17	38.55
4	12.566	3.54	24	452.39	21.27	44	1520.53	38.99
4½	15.904	3.99	24½	471.44	21.71	44½	1555.29	39.44
5	19.635	4.43	25	490.88	22.16	45	1590.43	39.88
5½	23.758	4.87	25½	510.71	22.60	45½	1625.97	40.32
6	28.274	5.32	26	530.93	23.04	46	1661.91	40.77
6½	33.183	5.76	26½	551.55	23.49	46½	1698.23	41.21
7	38.485	6.20	27	572.56	23.93	47	1734.95	41.65
7½	44.179	6.65	27½	593.96	24.37	47½	1772.06	42.10
8	50.266	7.09	28	615.75	24.81	48	1809.56	42.58
8½	56.745	7.53	28½	637.94	25.26	48½	1847.46	42.98
9	63.617	7.98	29	660.52	25.70	49	1885.75	43.43
9½	70.882	8.42	29½	683.49	26.14	49½	1924.43	43.87
10	78.540	8.86	30	706.86	26.59	50	1963.50	44.31
10½	86.590	9.30	30½	730.62	27.03	50½	2002.97	44.75
11	95.03	9.75	31	754.77	27.47	51	2042.83	45.20
11½	103.87	10.19	31½	779.31	27.92	51½	2083.08	45.64
12	113.10	10.63	32	804.25	28.36	52	2123.72	46.08
12½	122.72	11.08	32½	829.58	28.80	52½	2164.76	46.53
13	132.73	11.52	33	855.30	29.25	53	2206.19	46.97
13½	143.14	11.96	33½	881.41	29.69	53½	2248.01	47.41
14	153.94	12.41	34	907.92	30.13	54	2290.23	47.86
14½	165.13	12.85	34½	934.82	30.57	54½	2332.83	48.30
15	176.72	13.29	35	962.11	31.02	55	2375.83	48.74
15½	188.69	13.74	35½	989.80	31.46	55½	2419.23	49.19
16	201.06	14.18	36	1017.88	31.90	56	2463.01	49.63
16½	213.83	14.62	36½	1046.35	32.35	56½	2507.19	50.07
17	226.98	15.07	37	1075.21	32.79	57	2551.76	50.51
17½	240.53	15.51	37½	1104.47	33.23	57½	2596.73	50.96
18	254.47	15.95	38	1134.12	33.68	58	2642.09	51.40
18½	268.80	16.40	38½	1164.16	34.12	58½	2687.84	51.84
19	283.53	16.84	39	1194.59	34.56	59	2733.89	52.29
19½	298.65	17.28	39½	1225.42	35.01	59½	2780.51	52.73
20	314.16	17.72	40	1256.64	35.45	60	2827.74	53.17
20½	330.06	18.17	40½	1288.25	35.89			

DECIMALS OF A FOOT FOR EACH $\frac{1}{64}$ OF AN INCH.

Inch.	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
0	0	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
$\frac{1}{64}$	.0013	.0846	.1680	.2513	.3346	.4180	.5013	.5846	.6680	.7513	.8346	.9180
$\frac{1}{32}$	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
$\frac{3}{64}$	.0039	.0872	.1706	.2539	.3372	.4206	.5039	.5872	.6706	.7539	.8372	.9206
$\frac{1}{16}$	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
$\frac{5}{64}$	.0065	.0898	.1732	.2565	.3398	.4232	.5065	.5898	.6732	.7565	.8398	.9232
$\frac{3}{32}$	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
$\frac{7}{64}$	.0091	.0924	.1758	.2591	.3424	.4258	.5091	.5924	.6758	.7591	.8424	.9258
$\frac{1}{8}$	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
$\frac{9}{64}$	.0117	.0951	.1784	.2617	.3451	.4284	.5117	.5951	.6784	.7617	.8451	.9284
$\frac{5}{32}$	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
$\frac{11}{64}$	.0143	.0977	.1810	.2643	.3477	.4310	.5143	.5977	.6810	.7643	.8477	.9310
$\frac{3}{16}$	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
$\frac{13}{64}$	.0169	.1003	.1836	.2669	.3503	.4336	.5169	.6003	.6836	.7669	.8503	.9336
$\frac{7}{32}$	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
$\frac{15}{64}$	.0195	.1029	.1862	.2695	.3529	.4362	.5195	.6029	.6862	.7695	.8529	.9362
$\frac{1}{4}$	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
$\frac{17}{64}$	.0221	.1055	.1888	.2721	.3555	.4388	.5221	.6055	.6888	.7721	.8555	.9388
$\frac{9}{32}$	.0234	.1068	.1901	.2734	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401
$\frac{19}{64}$	.0247	.1081	.1914	.2747	.3581	.4414	.5247	.6081	.6914	.7747	.8581	.9414
$\frac{5}{16}$	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
$\frac{21}{64}$	.0273	.1107	.1940	.2773	.3607	.4440	.5273	.6107	.6940	.7773	.8607	.9440
$\frac{11}{32}$	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
$\frac{23}{64}$	.0299	.1133	.1966	.2799	.3633	.4466	.5299	.6133	.6966	.7799	.8633	.9466
$\frac{3}{8}$	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
$\frac{25}{64}$	.0326	.1159	.1992	.2826	.3659	.4492	.5326	.6159	.6992	.7826	.8659	.9492
$\frac{13}{32}$	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7105	.7839	.8672	.9505
$\frac{27}{64}$	.0352	.1185	.2018	.2852	.3685	.4518	.5352	.6185	.7018	.7852	.8685	.9518
$\frac{7}{16}$	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
$\frac{29}{64}$	.0378	.1211	.2044	.2878	.3711	.4544	.5378	.6211	.7044	.7878	.8711	.9544
$\frac{15}{32}$	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
$\frac{31}{64}$	.0404	.1237	.2070	.2904	.3737	.4570	.5404	.6237	.7070	.7904	.8737	.9570
$\frac{1}{2}$	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
$\frac{33}{64}$	.0430	.1263	.2096	.2930	.3763	.4596	.5430	.6263	.7096	.7930	.8763	.9596
$\frac{17}{32}$	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
$\frac{35}{64}$	.0456	.1289	.2122	.2956	.3789	.4622	.5456	.6289	.7122	.7956	.8789	.9622
$\frac{9}{16}$	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
$\frac{37}{64}$	.0482	.1315	.2148	.2982	.3815	.4648	.5482	.6315	.7148	.7982	.8815	.9648
$\frac{19}{32}$	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
$\frac{39}{64}$	.0508	.1341	.2174	.3008	.3841	.4674	.5508	.6341	.7174	.8008	8841	.9674
$\frac{5}{8}$	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
$\frac{41}{64}$	.0534	.1367	.2201	.3034	.3867	.4701	.5534	.6367	.7201	.8034	.8867	.9701
$\frac{21}{32}$	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
$\frac{43}{64}$	.0560	.1393	.2227	.3060	.3893	.4727	.5560	.6393	.7227	.8060	.8893	.9727
$\frac{11}{16}$	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
$\frac{45}{64}$	.0586	.1419	.2253	.3086	.3919	.4753	.5586	.6419	.7253	.8086	.8919	.9753
$\frac{23}{32}$	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
$\frac{47}{64}$	.0612	.1445	.2279	.3112	.3945	.4779	.5612	.6445	.7279	.8112	.8945	.9779
$\frac{3}{4}$	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792

DECIMALS OF A FOOT FOR EACH $\frac{1}{64}$ OF AN INCH—(*Continued*).

Inch.	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
$\frac{49}{64}$	.0638	.1471	.2305	.3138	.3971	.4805	.5638	.6471	.7305	.8138	.8971	.9805
$\frac{25}{32}$	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	8151	.8984	.9818
$\frac{51}{64}$	.0664	.1497	.2331	.3164	.3997	.4831	.5664	.6497	.7331	.8164	.8997	.9831
$\frac{13}{16}$	.0677	.1510	.2344	.3177	.4010	.4344	.5677	.6510	.7344	8177	9010	.9844
$\frac{53}{64}$	.0690	.1523	.2357	.3190	.4023	.4857	.5690	.6523	.7357	.8190	.9023	.9857
$\frac{27}{32}$	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
$\frac{55}{64}$	.0716	.1549	.2383	.3216	.4049	.4883	.5716	.6549	.7383	.8216	.9049	.9883
$\frac{7}{8}$	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
$\frac{57}{64}$	.0742	.1576	.2409	.3242	.4076	.4909	.5742	.6576	.7409	.8242	.9076	.9909
$\frac{29}{32}$	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	8255	.9089	.9922
$\frac{59}{64}$	.0768	.1602	.2435	.3268	.4102	.4935	.5768	.6602	.7435	.8268	.9102	.9935
$\frac{15}{16}$	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
$\frac{61}{64}$	.0794	.1628	.2461	.3294	.4128	.4961	.5794	.6628	.7461	.8294	.9128	.9961
$\frac{31}{32}$	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974
$\frac{63}{64}$	.0820	.1654	.2487	.3320	.4154	.4987	.5820	.6654	.7487	.8320	.9154	.9987
1												1.0000

DECIMALS OF AN INCH FOR EACH $\frac{1}{64}$TH.

$\frac{1}{32}$ds.	$\frac{1}{64}$ths.	Decimal.	Fraction.	$\frac{1}{32}$ds.	$\frac{1}{64}$ths.	Decimal.	Fraction.
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	$\frac{1}{16}$	18	36	.5625	$\frac{9}{16}$
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	$\frac{1}{8}$	20	40	.625	$\frac{5}{8}$
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	$\frac{3}{16}$	22	44	.6875	$\frac{11}{16}$
	13	.203125			45	703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	$\frac{1}{4}$	24	48	.75	$\frac{3}{4}$
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	$\frac{5}{16}$	26	52	.8125	$\frac{13}{16}$
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	$\frac{3}{8}$	28	56	.875	$\frac{7}{8}$
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	$\frac{7}{16}$	30	60	.9375	$\frac{15}{16}$
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	$\frac{1}{2}$	32	64	1.	1

FIRST AID TO THE INJURED.

USEFUL SUGGESTIONS IN CASES OF ACCIDENTS TO MECHANICS.

ELECTRIC SHOCK.—The patient should be immediately placed in position for artificial respiration, preferably on a table with a cushion under his shoulders to elevate them slightly. Then bring his arms down until his hands rest on his chest, grasp his wrists and press firmly against the lower walls of the chest for a few seconds, then raise the arms outward and upward until the hands meet beyond the head, drawing firmly upward for a few seconds; repeat this procedure ten or fifteen times a minute.

BLEEDING.—If blood spurts from wound, an artery is divided; bind limb tightly above with India-rubber tubing, strap, handkerchief, or scarf, or bend the limb forcibly at next joint above wound, or press flat hand or stone where blood is flowing. If blood flows freely, but does not spurt, a vein is divided; then apply same measures as in case of wounded artery, but below the wound. If scalp is wounded make a pad of cloth or waste, and bandage very tightly over wound with folded pocket-handkerchief.

BURNS AND SCALDS.—Apply lint, cotton, wool, or waste soaked in oil and lime-water, and bind the same on with handkerchief. If necessary to remove clothes cut them off by running knife or scissors along seams.

BROKEN LEG.—Pull on leg steadily and firmly until it is of same length as sound one. Roll up a coat or empty sack into form of a cushion, carefully place leg upon it, then bind the two together with scarfs or handkerchiefs. Do not lift patient from the ground until stretcher is close at hand. Take great pains, by careful lifting, to prevent broken bone coming through skin.

BROKEN THIGH.—Take hold of ankle and, by steady traction, pull limb to same length as sound one; another person must then tie knees together, and afterward the ankles. Both limbs should then be laid over a sack of straw, or folded coat, so as to bend the knees. Patient should on no account be moved until stretcher or cart is close at hand.

Broken Arm.—Pull arm to length of sound one. Apply two splints, one outside and the other inside, binding them firmly on with pocket-handkerchiefs. The best splints are made by folding newspapers to necessary length, binding them above and below seat of fracture; anything hard and light, of suitable size, would act equally well; for instance, wood, pasteboard. twigs, leather, etc.

A FEW ODDS AND ENDS FOR THE NOON-HOUR.

A Very Deceptive Problem.—Cut a piece of paper 8 inches square, containing 64 square inches, to fill a space 5×13 inches and containing 65 square inches.

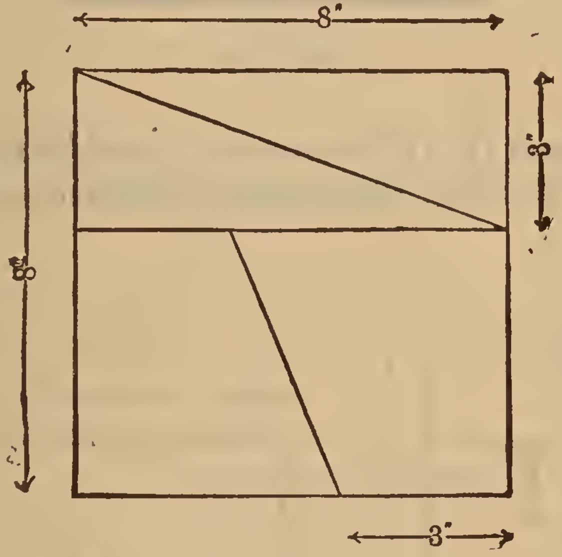

Fig. 177.

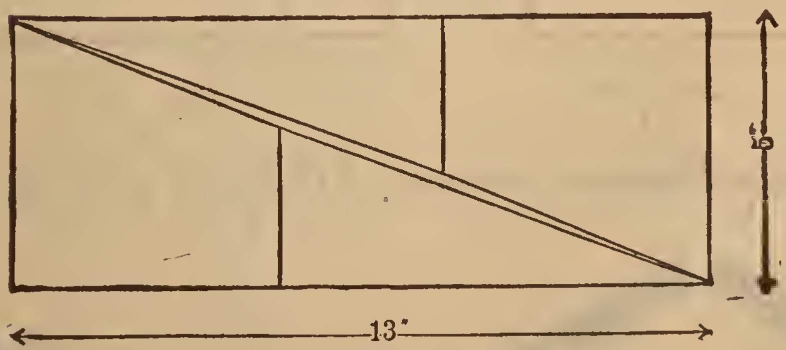

Fig. 178.

Cut the square piece of paper as shown by Fig. 177 and put together as shown by Fig. 178, it will then measure 5×13 inches, but if the sides of the 13-inch figure are kept straight there

will be an opening in the centre as shown. This explains the extra inch.

Which line is the longer, the horizontal or the perpendicular in Fig. 179? Speak quick.

FIG. 179.

TO CUT A BLOCK 12×12 INCHES TO FILL A HOLE 9×16 INCHES.—Cut as shown by Fig. 180 and put together as shown by Fig. 181.

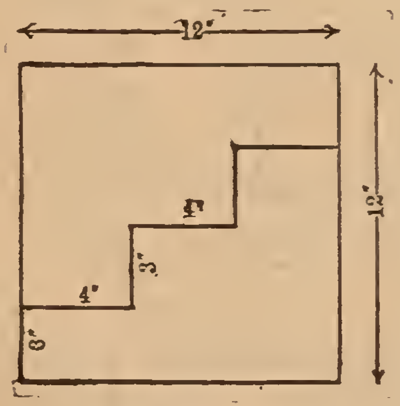

FIG. 180.

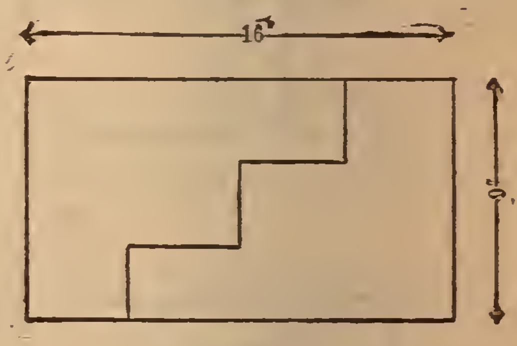

FIG. 181.

Which is the greater distance, *A* to *B* or *B* to *C*, Fig. 182?

FIG. 182.

Draw Fig. 183 without lifting the point of the pencil from the paper, making one continuous line.

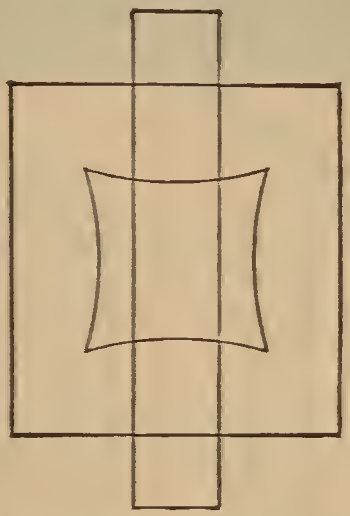

FIG. 183.

TO CUT A FIVE-POINT STAR AT ONE CUT.—Take a square piece of paper and fold it as shown by Fig. 184, 1 to 5, the first

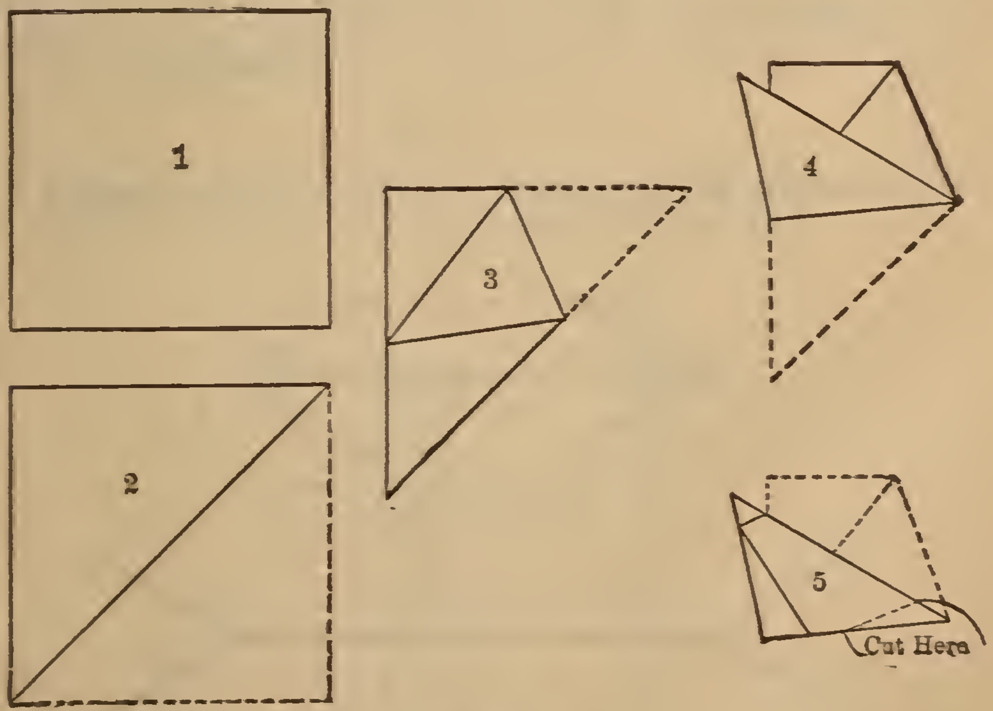

FIG. 184.

fold is shown at 2, the second fold is shown at 3, etc., when folded cut on the line shown in 5.

THE LEAKING-SHIP PROBLEM.—A ship at sea strikes a rock and knocks a hole in the bottom 8×15 inches. The ship's carpenter has a piece of board 10×12 inches. How can he cut it to fill the hole?

Cut it as shown by Fig. 185, and put together as shown by Fig. 186.

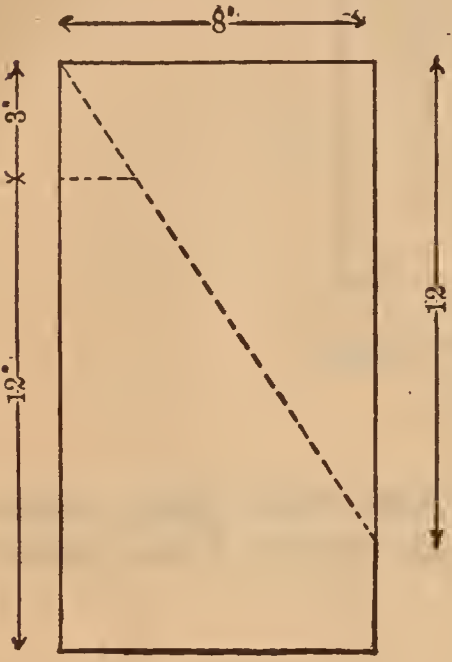

FIG. 185.

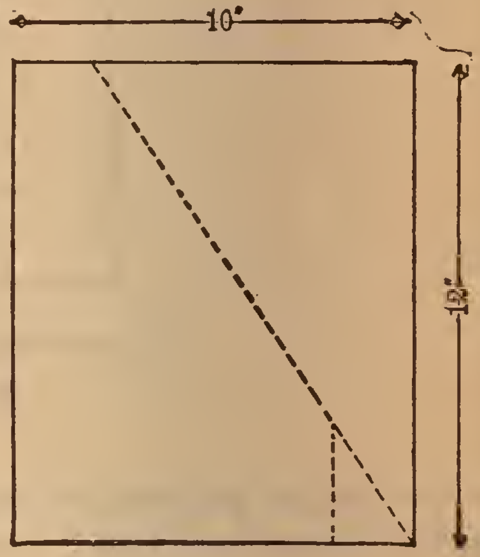

FIG. 186.

Which of the horizontal lines in Fig. 187 is the longer?

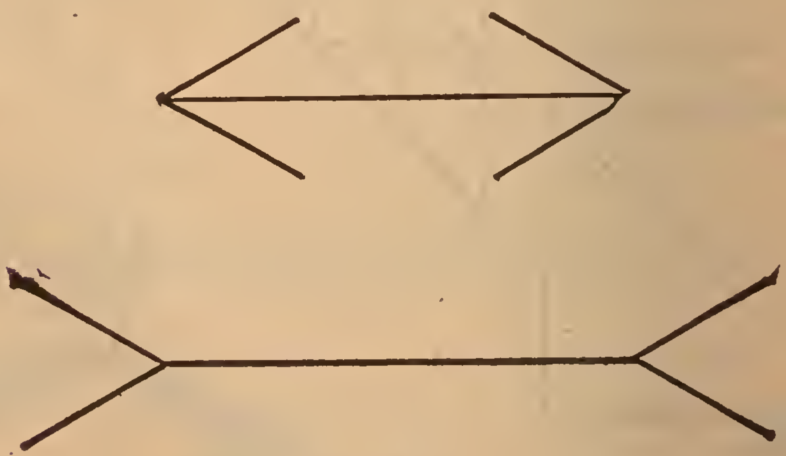

FIG. 187.

Which of the lower diagonal lines in Fig. 188 is in line with the line above.

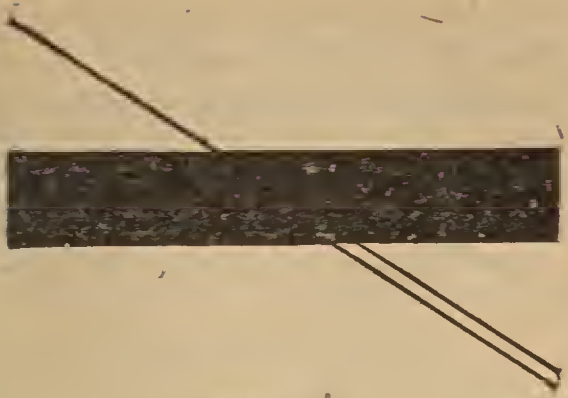

FIG. 188.

Are the horizontal lines in Fig. 189 parallel or not?

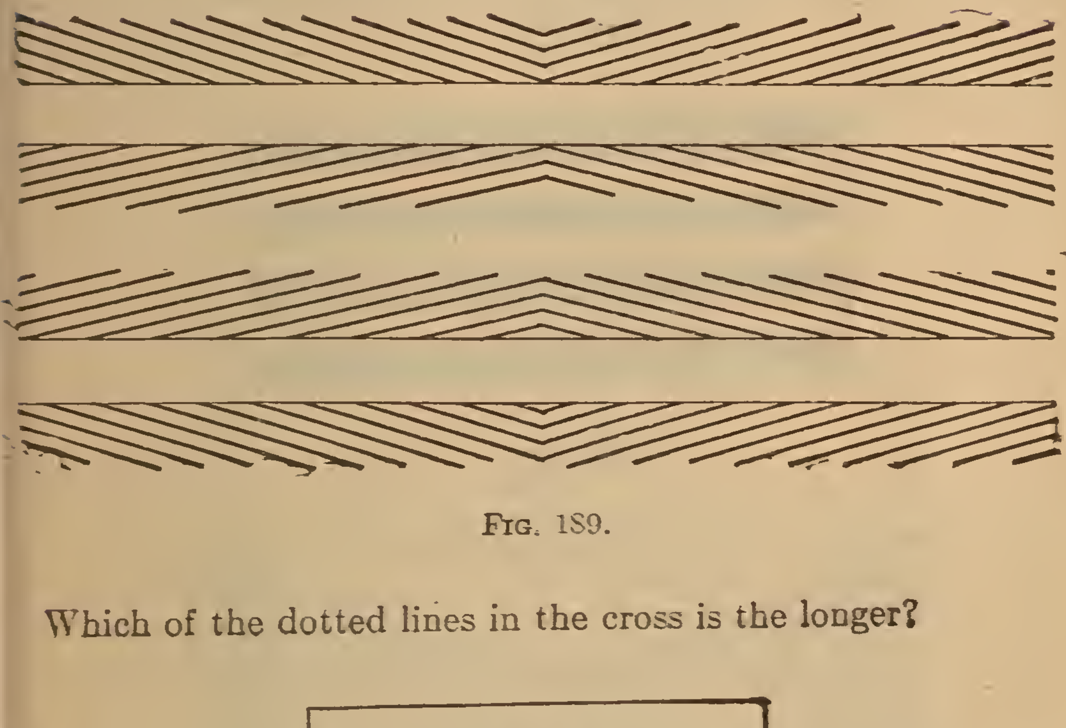

FIG. 189.

Which of the dotted lines in the cross is the longer?

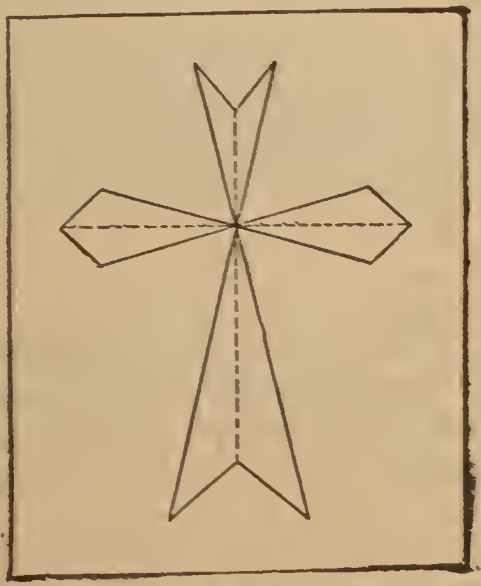

FIG. 190.

Which of the circular sections is the longer, *A* or *B*?

Are the heavy lines in Fig. 192 parallel?

Fig. 193 shows a perfectly straight rule laid over a number of concentric circular rings. As will be seen it gives the rule a

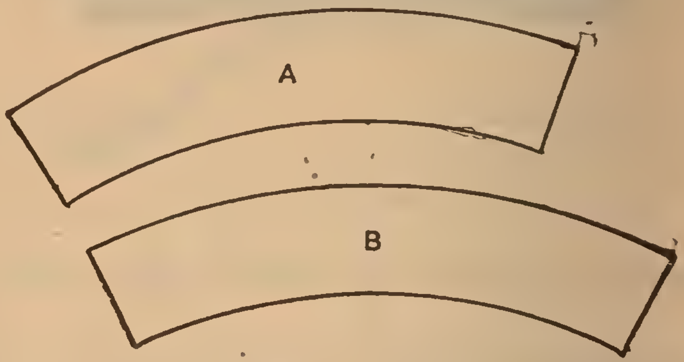

FIG. 191.

FIG. 192.

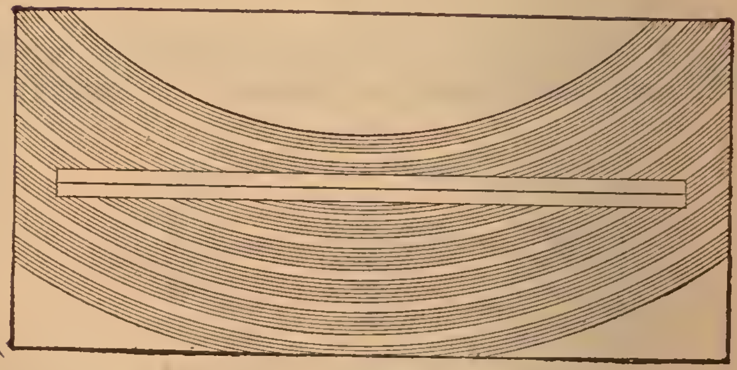

FIG. 193.

curved appearance. The circular rings also appear distorted, as the rings on one side of the rule do not appear to be a continuation of those on the other side, but this can be proved by sighting along the lines.

TOTIN' THE HOD.

When I near some houses building,
  With all sorts of stuff around—
Lime and sand and bricks and lumber,
  Dumped upon the uneven ground;
When I see the bed of mortar,
  With a pile all tempered right,
When I see the man that's tending,
  As he works with all his might—
Fills the hod to overflowing,
  Stoops and shoulders it, and then
Mounts the steps or climbs the ladder
  To supply the workingmen;
I don't think of town improvements,
  Nor of scanty, well-earned pelf,
But there comes a kindly feeling—
  For I've "toted" some myself.

Once again I hear the clinking
  Of the trowel on the wall.
Once again I see the sunshine
  On the blinding whiteness fall
Of the lime within the slush-box—
  Watch it crack and hear it boil;
From its rattling detonations
  I can feel myself recoil.
But all these—I pass them over,
  As I watch him with his hoe,
See him load his empty hod up,
  Then into the building go.
But it's not of town improvements,
  Nor of scanty, well-earned pelf,
It's of former days I'm thinking,
  When I "toted" some myself.

And I think, as I am looking,
  If I'd never helped to do
Work that strained and stretched each muscle—
  Gave me soreness through and through—
I had never felt this feeling,
  Kindly, thoughtful, for the man
Who with hod and hoe and shovel,
  Travels in improvement's van.
So you must not count me foolish,
  And perhaps a trifle odd,
If I stop and hold some converse
  With the man beneath the hod.
For you'd have a kindly feeling,
  Far removed from paltry pelf,
Far removed from town improvements,
  If you'd "toted" some yourself.

JOHN L. SHROY, in *Carpentry and Building.*

WAGE-TABLE.

Explanation.—Find the number of days or hours employed, in the left-hand columns, and follow this line out to the column under the rate per day or hour, where will be found the sum due.

Rate per hour, cents........		25	28	31.25	34.38	37.5	40	40.62	43.75	46.87	50	53.12	56.25	59.37	62.5	65.62	68.75	71.87	75
Rate per day, dollars......		2.00	2.25	2.50	2.75	3.00	3.20	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00
Days of 8 Hours.	Hours.	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct
	½	.13	.14	16	.17	19	.20	.20	.22	.23	.25	.26	.28	.30	31	.33	.34	.36	.38
	1	.25	.28	.31	.34	.38	.40	.41	.44	.47	.50	.53	.56	.59	.63	.66	.69	.72	.75
	½	.38	.42	.47	52	.56	.60	.61	.66	.70	.75	.80	.84	.89	.94	.99	1.03	1.08	1.13
¼	2	.50	.56	.63	69	.75	.80	.81	.88	.94	1.00	1.06	1.13	1.19	1.25	1.31	1.38	1.44	1.50
	½	.63	70	.78	.86	.94	1.00	1.02	1.09	1.17	1.25	1.33	1.41	1.49	1.56	1.64	1.72	1.80	1.88
	3	.75	.84	.94	1.03	1.13	1.20	1.22	1.31	1.41	1.50	1.59	1.69	1.78	1.88	1.97	2.06	2.16	2.25
	½	.88	.98	1 09	1 20	1.31	1.40	1.42	1.53	1.64	1.75	1.85	1.97	2.08	2.19	2.30	2.41	2.52	2.63
½	4	1.00	1.13	1.25	1.38	1.50	1.60	1.63	1.75	1.88	2.00	2.12	2.25	2.39	2.50	2.62	2.75	2.87	3.00
	½	1.13	1.26	1.41	1 55	1.69	1.80	1.83	1.97	2.11	2.25	2.39	2.53	2.67	2.81	2.95	3.09	3.23	3.38
	5	1.25	1.41	1.56	1.72	1.88	2.00	2.03	2.19	2.34	2.50	2.66	2.81	2.97	3.13	3.28	3.44	3.59	3.75
	½	1.38	1.55	1.72	1.89	2.06	2.20	2.23	2.41	2.58	2.75	2.92	3.09	3.26	3.44	3.61	3.78	3.95	4.13
¾	6	1.50	1 69	1.88	2.06	2.25	2.40	2.44	2.63	2.81	3.00	3.19	3.38	3.56	3.75	3.94	4.13	4.31	4.50
	½	1.63	1.83	2.03	2.23	2.44	2.60	2.64	2.84	3.05	3.25	3.45	3.66	3.86	4.07	4.27	4.47	4.67	4.88
	7	1.75	1.97	2.19	2.41	2.63	2.80	2.84	3.06	3.28	3.50	3.72	3.93	4.16	4.38	4.59	4.81	5.03	5.25
	½	1.88	2.11	2.34	2.58	2.81	3.00	3.05	3.28	3.52	3.75	3.98	4.22	4.45	4.69	4.92	5.16	5.39	5.63
1 day	8	2.00	2.25	2.50	2.75	3.00	3.20	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00
	½	2.13	2.39	2.66	2.92	3.19	3.40	3.45	3.72	3.98	4.25	4.51	4.78	5.05	5.31	5.58	5.84	6.11	6.38
	9	2.25	2.53	2.81	3.09	3.38	3.60	3.66	3.94	4.22	4.50	4.78	5.06	5.34	5.63	5.91	6.19	6.47	6.75
	½	2.38	2.67	2.97	3.27	3.56	3.80	3.86	4.16	4.45	4.75	5.05	5.34	5.64	5.94	6.24	6.53	6.83	7.13
1¼	10	2.50	2.81	3.13	3.44	3.75	4.00	4.06	4.38	4.69	5.00	5.31	5.63	5.94	6.25	6.56	6.88	7.19	7.50
	½	2.63	2.95	3.28	3.61	3.94	4.20	4.27	4.59	4.92	5.25	5.58	5.91	6.24	6.56	6.89	7.22	7.55	7.88
	11	2.75	3.09	3.41	3.78	4.13	4.40	4.47	4.81	5.16	5.50	5.84	6.19	6.53	6.88	7.22	7.56	7.91	8.25
	½	2.88	3.23	3.59	3.95	4.31	4.60	4.67	5.03	5.30	5.75	6.11	6.47	6.83	7.19	7.55	7.91	8.27	8.63
1½	12	3.00	3.38	3.75	4.13	4.50	4.80	4.88	5.25	5.63	6.00	6.38	6.75	7.13	7.50	7.87	8.25	8.62	9.00

WAGE-TABLE—(*Continued*).

Explanation.—Find the number of days or hours employed, in the left-hand columns, and follow this line out to the column under the rate per day or hour, where will be found the sum due.

Rate per hour, cents........		25	28	31.25	34.38	37.5	40	40.62	43.75	46.87	50	53.12	56.25	59.37	62.5	65.62	68.75	71.87	75
Rate per day, dollars......		2.00	2.25	2.50	2.75	3.00	3.20	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00
Days of 8 Hours.	Hours.	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct
	12½	3.13	3.51	3.91	4.30	4.69	5.00	5.08	5.47	5.86	6.25	6.64	7.03	7.42	7.81	8.20	8.59	8.98	9.38
	13	3.25	3.66	4.06	4.47	4.88	5.20	5.28	5.69	6.00	6.50	6.91	7.31	7.72	8.13	8.53	[illegible]	9.34	9.75
	½	3.38	3.80	4.22	4.64	5.06	5.40	5.48	5.91	6.33	6.75	7.17	7.59	8.01	8.44	8.86	9.28	9.70	10.13
1¾	14	3.50	3.94	4.38	4.81	5.25	5.60	5.69	6.13	6.56	7.00	7.44	7.88	8.31	[illegible]	9.19	[illegible]	10.06	10.50
	½	3.63	4.08	4.53	4.98	5.44	5.80	5.89	6.34	6.80	7.25	7.71	8.16	[illegible]	9.07	9.52	[illegible]	10.42	[illegible]
	15	3.75	4.22	4.69	5.16	5.63	6.00	6.09	6.56	7.03	7.50	7.97	8.44	[illegible]	9.38	9.84	[illegible]	10.78	11.25
	½	3.88	4.36	4.84	5.33	5.81	6.20	6.30	6.78	7.27	7.75	8.23	8.72	9.20	[illegible]	[illegible]	10.66	11.14	11.63
2 days	16	4.00	4.50	5.00	5.50	6.00	6.40	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50	11.00	11.50	12.00
	½	4.13	4.64	5.16	5.67	6.19	6.60	6.70	7.22	7.73	8.25	8.76	9.28	9.80	[illegible]	[illegible]	11.34	11.86	[illegible]
	17	4.25	4.78	5.31	5.84	6.38	6.80	6.91	7.44	7.97	8.50	9.03	9.56	10.09	10.63	11.16	[illegible]	12.22	12.75
	½	4.38	4.92	5.47	6.02	6.56	7.00	7.11	7.66	8.20	8.75	9.30	9.84	10.39	10.94	11.49	[illegible]	12.58	13.13
2¼	18	4.50	5.06	5.63	6.19	6.75	7.20	7.31	7.88	8.44	9.00	9.56	10.13	10.69	11.25	11.81	12.38	12.94	13.50
	½	4.63	5.20	5.78	6.36	6.94	7.40	7.52	8.09	8.67	9.25	9.83	10.41	10.99	11.56	12.14	12.72	13.30	13.88
	19	4.75	5.34	5.94	6.53	7.13	7.60	7.72	8.31	8.91	9.50	10.09	10.69	11.28	11.88	12.47	13.06	13.66	14.25
	½	4.88	5.48	6.09	6.70	7.31	7.80	7.92	8.53	9.14	9.75	10.36	10.97	11.58	12.19	12.80	13.41	14.04	14.63
2½	20	5.00	5.63	6.25	6.88	7.50	8.00	8.13	8.75	9.38	10.00	10.63	11.25	11.88	12.50	13.12	13.75	14.37	15.00
	½	5.13	5.76	6.41	7.05	7.69	8.20	8.33	8.97	9.61	10.25	11.89	11.53	12.17	12.81	13.45	14.09	[illegible]	15.38
	21	5.25	5.91	6.56	7.22	7.88	8.40	8.53	9.19	9.84	10.50	11.16	11.81	12.47	13.13	13.78	14.44	15.09	15.75
	½	5.38	6.04	6.72	7.39	8.06	8.60	8.73	9.41	10.08	10.75	11.42	12.09	12.76	13.44	14.11	14.78	[illegible]	16.13
2¾	22	5.50	6.19	6.88	7.56	8.25	8.80	8.94	9.63	10.31	11.00	11.69	12.38	13.06	13.75	14.44	15.13	[illegible]	16.50
	½	5.63	6.33	7.03	7.73	8.44	9.00	9.14	9.84	10.55	11.25	12.96	12.66	13.36	14.07	14.77	15.47	16.17	16.83
	23	5.75	6.47	7.19	7.91	8.63	9.20	9.34	10.06	10.78	11.50	12.22	12.93	13.66	14.38	15.09	15.81	16.53	17.25
	½	5.88	6.61	7.34	8.08	8.81	9.40	9.55	10.28	11.02	11.75	12.48	13.22	13.95	14.69	15.42	16.16	16.89	17.63
3 days	24	6.00	6.75	7.50	8.25	9.00	9.60	9.75	10.50	11.25	12.00	12.75	13.50	14.25	15.00	15.75	16.50	17.25	18.00

WAGE-TABLE—(*Continued*).

Explanation.—Find the number of days or hours employed, in the left-hand columns, and follow this line out to the column under the rate per day or hour, where will be found the sum due.

Rate per hour, cents........		25	28	31.25	34.38	37.5	40	40.62	43.75	46.87	50	53.12	56.25	59.37	62.5	65.62	68.75	71.87	75
Rate per day, dollars.		2.00	2.25	2.50	2.75	3.00	3.20	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00
Days of 8 Hours.	Hours.	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct
	24½	6.13	6.89	7.66	8.42	9.19	9.80	9.95	10.72	11.48	12.25	13.01	13.78	14.55	15.31	16.08	16.84	17.61	18.38
	25	6.25	7.03	7.81	8.59	9.38	10.00	10.16	10.94	11.72	12.50	13.28	14.06	14.84	15.63	16.41	17.17	17.97	18.75
	½	6.38	7.17	7.97	8.77	9.56	10.20	10.36	11.16	11.95	12.75	13.55	14.34	15.14	15.94	16.74	17.53	18.33	19.13
3¼	26	6.50	7.31	8.13	8.94	9.75	10.40	10.56	11.38	12.19	13.00	13.81	14.63	15.44	16.25	17.14	17.88	18.69	19.50
	½	6.63	7.45	8.28	9.11	9.94	10.60	10.77	11.59	12.42	13.25	14.08	14.91	15.74	16.56	17.39	18.22	19.05	19.88
	27	6.75	7.59	8.44	9.28	10.13	10.80	10.97	11.81	12.66	13.50	14.34	15.19	16.03	16.88	17.72	18.56	19.41	20.25
	½	6.88	7.73	8.59	9.45	10.31	11.00	11.17	12.03	12.89	13.75	14.61	15.47	16.33	17.19	18.05	18.19	19.77	20.63
3½	28	7.00	7.88	8.75	9.63	10.50	11.20	11.38	12.25	13.13	14.00	14.88	15.75	16.63	17.50	18.37	19.25	20.12	21.00
	½	7.13	8.01	8.91	9.80	10.69	11.40	11.58	12.47	13.36	14.25	15.14	16.03	16.92	17.81	18.70	19.59	20.48	21.38
	29	7.25	8.16	9.03	9.97	10.88	11.60	11.78	12.69	13.59	14.50	15.41	16.31	17.22	18.13	19.03	19.94	20.84	21.75
	½	7.38	8.30	9.22	10.14	11.06	11.80	11.98	12.91	13.83	14.75	15.67	16.59	17.51	18.44	19.36	20.28	21.20	22.13
3¾	30	7.50	8.44	9.38	10.31	11.25	12.00	12.19	13.13	14.06	15.00	15.94	16.88	17.81	18.75	19.69	20.63	21.56	22.50
	½	7.63	8.58	9.53	10.48	11.44	12.20	12.39	13.31	14.30	15.25	16.21	17.16	18.11	19.07	20.02	20.97	21.92	22.88
	31	7.75	8.72	9.69	10.66	11.63	12.40	12.59	13.56	14.53	15.50	16.47	17.44	18.41	19.38	20.34	21.31	22.28	23.25
	½	7.88	8.86	9.84	10.83	11.81	12.60	12.80	13.78	14.77	15.75	16.73	17.72	18.70	19.69	20.67	21.66	22.64	23.63
4 days	32	8.00	9.00	10.00	11.00	12.00	12.80	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	24.00
	½	8.13	9.14	10.16	11.17	12.19	13.00	13.20	14.22	15.23	16.25	17.26	18.28	19.30	20.31	21.33	22.34	23.36	24.38
	33	8.25	9.28	10.31	11.34	12.38	13.20	13.41	14.44	15.47	16.50	17.53	18.56	19.59	20.63	21.66	22.69	23.72	24.75
	½	8.38	9.42	10.47	11.52	12.56	13.40	13.61	14.66	15.70	16.75	17.80	18.84	19.89	20.94	21.99	23.03	24.08	25.13
4¼	34	8.50	9.56	10.63	11.69	12.75	13.60	13.81	14.88	15.94	17.00	18.06	19.13	20.19	21.25	22.31	23.38	24.44	25.50
	½	8.63	9.70	10.78	11.86	12.94	13.80	14.02	15.09	16.17	17.25	18.33	19.41	20.49	21.56	22.64	23.72	24.80	25.88
	35	8.75	9.84	10.94	12.03	13.13	14.00	14.22	15.31	16.41	17.50	18.59	19.69	20.78	21.88	22.97	24.06	25.16	26.25
	½	8.88	9.98	11.09	12.20	13.31	14.20	14.42	15.53	16.64	17.75	18.85	19.97	21.08	22.19	23.30	24.41	25.52	26.63
4½	36	9.00	10.13	11.25	12.38	13.50	14.40	14.63	15.75	16.88	18.00	19.12	20.25	21.38	22.50	23.62	24.75	25.87	27.00

WAGE-TABLE—(*Continued*).

Explanation.—Find the number of days or hours employed, in the left-hand columns, and follow this line out to the column under the rate per day or hour, where will be found the sum due.

Rate per hour, cents........		25	28	31.25	34.38	37.5	40	40.62	43.75	46.87	50	53.12	56.25	59.37	62.5	65.62	68.75	71.87	75
Rate per day, dollars......		2.00	2.25	2.50	2.75	3.00	3.20	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00
Days of 8 Hours.	Hours	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct	$ ct
	36½	9.13	10.26	11.41	12.55	13.69	14.60	14.83	15.97	17.11	18.25	19.38	20.53	21.68	22.81	23.95	25.09	26.23	27.38
	37	9.25	10.41	11.56	12.72	13.88	14.80	15.03	16.19	17.34	18.50	19.65	20.81	21.97	23.13	24.27	25.44	26.59	27.75
	½	9.38	10.55	11.72	12.89	14.06	15.00	15.23	16.41	17.58	18.75	19.92	21.09	22.27	23.44	24.60	25.78	26.95	28.13
4¾	38	9.50	10.69	11.88	13.06	14.25	15.20	15.44	16.63	17.81	19.00	20.18	21.38	22.57	23.75	24.93	26.13	27.31	28.50
	½	9.63	10.83	12.03	13.23	14.44	15.40	15.64	16.84	18.05	19.25	20.45	21.66	22.87	24.06	25.26	26.47	27.67	28.88
	39	9.75	10.97	12.19	13.41	14.63	15.60	15.84	17.06	18.28	19.50	20.71	21.93	23.16	24.38	25.58	26.81	28.03	29.25
	½	9.88	11.11	12.34	13.58	14.81	15.80	16.05	17.28	18.52	19.75	20.97	22.22	23.46	24.69	25.92	27.16	28.39	29.63
5 days	40	10.00	11.25	12.50	13.75	15.00	16.00	16.25	17.50	18.75	20.00	21.24	22.50	23.75	25.00	26.25	27.50	28.75	30.00
	½	10.13	11.39	12.66	13.92	15.19	16.20	16.45	17.72	18.98	20.25	21.51	22.78	24.05	25.31	26.58	27.84	29.11	30.38
	41	10.25	11.53	12.81	14.09	15.38	16.40	16.66	17.94	19.22	20.50	21.78	23.06	24.34	25.63	26.91	28.19	29.47	30.75
	½	10.38	11.67	12.97	14.27	15.56	16.60	16.86	18.16	19.45	20.75	22.04	23.34	24.64	25.94	27.24	28.53	29.83	31.13
5¼	42	10.50	11.81	13.13	14.44	15.75	16.80	17.06	18.38	19.69	21.00	22.30	23.63	24.94	26.25	27.56	28.88	30.19	31.50
	½	10.63	11.95	13.28	14.61	15.94	17.00	17.27	18.59	19.92	21.25	22.57	23.91	25.24	26.56	27.89	29.22	30.55	31.88
	43	10.75	12.09	13.44	14.78	16.13	17.20	17.47	18.81	20.16	21.50	22.83	24.19	25.53	26.88	28.22	29.56	30.91	32.25
	½	10.88	12.23	13.59	14.95	16.31	17.40	17.67	19.03	20.39	21.75	23.10	24.47	25.83	27.19	28.55	29.91	31.27	32.63
5½	44	11.00	12.38	13.75	15.13	16.50	17.60	17.88	19.25	20.63	22.00	23.36	24.75	26.14	27.50	28.87	30.25	31.62	33.00
	½	11.13	12.51	13.91	15.30	16.69	17.80	18.08	19.47	20.86	22.25	23.63	25.03	26.42	27.81	29.20	30.59	31.98	33.38
	45	11.25	12.66	14.06	15.47	16.88	18.00	18.28	19.69	21.09	22.50	23.90	25.31	26.73	28.13	29.53	30.94	32.34	33.75
	½	11.38	12.80	14.22	15.64	17.06	18.20	18.48	19.91	21.33	22.75	24.17	25.59	27.01	28.44	29.86	31.28	32.70	34.13
5¾	46	11.50	12.94	14.38	15.81	17.25	18.40	18.69	20.13	21.56	23.00	24.43	25.88	27.32	28.75	30.19	31.63	33.06	34.50
	½	11.63	13.08	14.53	15.98	17.44	18.60	18.89	20.34	21.80	23.25	24.70	26.16	27.61	29.07	30.52	31.97	33.42	34.88
	47	11.75	13.22	14.69	15.16	17.63	18.80	19.09	20.56	22.03	23.50	24.96	26.44	27.92	29.38	30.84	32.31	33.78	35.25
	½	11.88	13.36	14.84	16.33	17.81	19.00	19.30	20.78	22.27	23.75	25.23	26.72	28.21	29.69	31.17	32.66	34.14	35.63
6 days	48	12.00	13.50	15.00	16.50	18.00	19.20	19.50	21.00	22.50	24.00	25.50	27.00	28.50	30.00	31.50	33.00	34.50	36.00

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